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Faculty of Social Sciences
Institute of Economic Studies

MASTER THESIS

Monetary Union of Belarus and Russia – Analysis of Possible Costs for the Belarusian Economy

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently, using only the listed resources and literature. The thesis has not been used to obtain a different or the same degree.

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Prague, July 23, 2013

Signature

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Abstract

The thesis analyses alignment of the Belarusian and Russian economies with the aim to infer on costs of the possible monetary union for Belarus. Having estimated a structural vector autoregression model with long-run restrictions, we conclude that the economies have shared common supply and external demand shocks, but other temporary fluctuations have been, in large, asymmetric. Structural discrepancies (as proven by the qualitative analysis) and differences in the monetary policy foci and transmission (as illustrated by the estimation results of Taylor rules and a monetary vector autoregression model) could account for increasing misalignment since 2010. In terms of the welfare costs for Belarus (evaluated with a New Keynesian dynamic stochastic general equilibrium model), the monetary union can be considered preferable to the current monetary policy of the National bank of the Republic of Belarus, while being inferior to the hypothetical inflation targeting regime. The welfare gap between the two arrangements reduces, if stronger domestic price flexibility and higher synchronization of productivity shocks can be assumed.

JEL Classification F33, F36, F41, E52
Keywords OCA, Monetary Policy, VAR, DSGE

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Acronyms

OCA Optimum Currency Area

NK DSGE New Keynesian dynamic stochastic general equilibrium

NBB National Bank of the Republic of Belarus

CBR Central Bank of the Russian Federation

RUR Russian Ruble

BYR Belarusian Ruble

USD US Dollar

VAR Vector Autoregression

VECM Vector Error Correction Model

IPI Industrial Production Index

GDP Gross Domestic Product

CPI Consumer Price Index

PPI Producer Price Index

FDI Foreign Direct Investment

IMF International Monetary Fund

PPP Purchasing Power Parity

EBRD European Bank for Reconstruction and Development

Master Thesis Proposal

Author	Nadzeya Laurentsyeva
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Proposed topic	Monetary Union of Belarus and Russia – Analysis of Possible Costs for the Belarusian Economy

Topic characteristics: The economies of Belarus and Russia being highly integrated, the idea of the monetary union between the countries has had long history. For instance, the initial terms of the treaty on the creation of the Union State between Belarus and Russia (1999) assumed the adoption of the Russian ruble in Belarus in 2004-2005. Corresponding research and official negotiations on prospective monetary arrangement were conducted in 2003-2004; yet, due to multiple reasons the implementation did not take place. Discussions on the possibility of the monetary union rearised in 2011. First, in May 2011 Belarus experienced a severe balance-of-payments crisis, during which the national currency was devalued by almost 200%. Although, in October 2011, the National Bank of the Republic of Belarus (NBB) officially switched to the floating exchange rate regime with the intention to implement inflation targeting, the after-crisis monetary policy has been defined vaguely and has been hampered by high inflation expectations and low level of credibility of the NBB. A number of economists and politicians, thus, suggest that the monetary union with Russia could contribute to the stabilization of inflation in Belarus and bring about other benefits of the common currency area. Second, in the end of 2011, the leaders of Russia, Belarus, and Kazakhstan signed a package of agreements on the Eurasian Economic Integration. One of the explicit long-term objectives is the creation of the monetary union of the member states. In this context, it seems relevant to analyze the alignment of the Belarusian and the Russian economies and consequently to evaluate the possible costs for

Belarus that could be associated with entering into the monetary union with Russia.

Contribution: The thesis will evaluate the idea of the monetary union of Belarus and Russia in terms of its possible costs for the Belarusian economy that may arise due to cyclical and structural asymmetry of the economies as well as due to misalignment of policy transmission mechanisms.

Data: real economic indicators (GDP, unemployment, exports, industrial production, etc); price indexes; monetary policies indicators; labor market and banking sector indicators.

Data sources: Databases of Statistical Offices of Belarus and Russia; databases of the NBB and the Central Bank of the Russian Federation (CBR).

Hypotheses are the following:
1. Despite long-dated history of integration, there is significant cyclical and structural misalignment between the Belarusian and the Russian economies due to asymmetry of shocks and different specializations of the economies.
2. There are substantial differences between current monetary policy responses to shocks in Belarus and Russia and their transmission mechanisms.
3. Welfare losses for the Belarusian economy associated with the possible monetary union will be higher than those implied by the inflation targeting regime and/or the effective monetary policy rule.

Methodology to be applied:
Hypothesis 1:

- Correlation coeffcients; Landesmann and Grubel-Lloyd indices.
- Structural VAR model with long-run restrictions.

Hypothesis 2:

- Taylor rules estimation; monetary VAR model with foreign sector.

Hypothesis 3:

- New-Keynesian DSGE framework for a small open economy.

Outline

1. Introduction
2. Background information. Qualitative analysis of the economies' alignment
3. Shock synchronisation and structural alignment
4. Alignment of the monetary policies and their transmission mechanisms.
5. Evaluation of welfare losses under alternative monetary regimes
6. Conclusion

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Chapter 1

Introduction

In May 2011, Belarus experienced a severe balance-of-payments crisis, during which the national currency was devalued by almost 200%, thus, discrediting the hybrid exchange rate policy conducted by the National Bank of the Republic of Belarus (NBB) since 2009. In October 2011, the monetary authorities of Belarus officially declared a switch from the soft-peg to the free-floating regime with the intention to implement inflation targeting. Yet, as the after-crisis monetary policy has been defined vaguely and has been hampered by high inflation expectations and low credibility of the NBB, the question on the appropriate exchange rate arrangement for the Belarusian economy remains open.

The monetary union with Russia could be considered as a viable alternative to the current monetary policy regime. The factors behind such proposition include intensive trade relations and high level of factor mobility between the countries. Adopting relatively more stable Russian ruble could contribute to the stabilization of inflation in Belarus and bring about other benefits such as reduction of transaction costs and risk premiums, access to cheaper credit resources, and stimulation of foreign direct investment inflows. At the same time, apart from direct costs of the new monetary arrangement, introducing the Russian ruble in Belarus would imply abandonment of the independent monetary policy and consequent loss of important adjustment mechanisms. The extent of these costs depends, in large, on the degree of the economies' alignment and on the role the Belarusian monetary policy currently plays to absorb shocks. Another important factor to consider is the feasibility of achieving macroeconomic stability in Belarus by reforming the own monetary policy institution that presently lacks independence, transparency, and credibility.

The objective of the present thesis is to analyze alignment of the Belarusian and Russian economies and, consequently, to infer on some costs of the possible monetary union for Belarus. We base the analysis on the framework developed within the Optimum Currency Area (OCA) theory, i.e. we evaluate some OCA criteria in terms of their contribution to the costs of fixing the exchange rate to the Russian ruble. We start by qualitatively assessing convergence of the Belarusian and Russian economies and proceed with econometric analysis of shock synchronization, policy rules and their transmission mechanisms. In order to measure shock symmetry we apply a structural Vector Autoregression (VAR) model with long-run restrictions that allows us to distinguish between temporary and permanent shocks. Monetary policy rules and their transmission mechanisms are compared by estimating Taylor rules and a VAR model with foreign sector. Finally, we set up a New Keynesian dynamic stochastic general equilibrium (NK DSGE) model for a small open economy to measure explicitly costs of the monetary union relative to alternative arrangements.

The thesis is structured as follows: Chapter 2 contains literature review on the OCA theory and its empirical applications; this chapter also provides a qualitative analysis of the Belarusian and Russian economies' convergence. Chapters 3 and 4 feature the analysis of cyclical alignment. Chapter 3 focuses on origins of fluctuations and presents estimations of shocks synchronization and structural symmetry of the economies. Chapter 4 compares responses to shocks and evaluates alignment of effective monetary policy rules and their transmission mechanisms. Chapter 5 summarizes the analysis by comparing welfare losses for the Belarusian economy generated under alternative monetary policy regimes. Chapter 6 concludes.

Chapter 2

Background Information

The present chapter provides background information on the thesis topic. Section 2.1 presents an overview of the monetary policy in Belarus. Section 2.2 features a brief literature review on the OCA theory and relevant empirical studies. Section 2.3 contains preliminary convergence analysis of the Belarusian and Russian economies.

2.1 Overview of the Modern Monetary Policy in the Republic of Belarus. Motivation for the Monetary Union with the Russian Federation

Following the collapse of the USSR and gradual dissolution of the Ruble Area, the new Belarusian currency was put into circulation in 1992. After unsuccessful liberalization of the exchange rate in 1994 with consequent depreciation and hyperinflation, the NBB (the National Bank of the Republic of Belarus) concentrated on the stabilization of the currency. Either the Russian Ruble (RUR) or the US Dollar (USD) were used as anchors; as a rule, the official exchange rate was periodically revised and set together with a fluctuation band. In 1999, Belarus and Russia signed a Treaty on the Creation of the Union State, followed, in November 2000, by an agreement to introduce common currency. In 2002, the countries approved a Joint Action Plan for the introduction of a common monetary unit. Under initial terms of the agreement, the RUR should have been adopted in Belarus in 2005 and a common currency should have been introduced in 2008. In the consequent years, the Belarusian monetary authorities aimed at fixing the BYR against the RUR and at stabilizing money supply growth. However, due to political tensions and disagreements about the arrangements of the monetary union, the integration process slowed down. From 2007 up to the end of 2008, conventional fixed exchange-rate regime (initially, with both the RUR and the USD and later only with the USD as anchor) was applied.

As repercussions of the global financial and economic crisis reached Belarus in late 2008, pegged against the USD the Belarusian ruble could not adjust as rapidly as the market demanded. In the beginning of 2009, the NBB switched the USD peg to the currency basket peg (Euro, USD, and RUR) with a 10% crawling band and devalued the BYR by 20.45% (NBB 2010). The after-crisis monetary policy was characterized by credit expansion driven by the pressure to meet targets of high output and wage growth. Monetary emission was largely used to finance state programs and to accelerate economic recovery. As the result, in 2010, the real GDP grew by 7.7%. At the same time, following significant increase of energy prices, the current account deficit reached nearly 15% of the GDP. Expansionary policies also resulted in rapid accumulation of the external debt that had risen from 25% of the GDP in 2008 to 45% in 2009 and 52.2% in 2010 (NBB Statistics Database).

Loose monetary policy in 2009-2010 combined with the current account deficit and growing foreign debt contributed to the accumulation of imbalances in the economy. Expectations of devaluation and inflation resulted in massive purchases of foreign currencies and withdrawals of FX-denominated deposits in the end of 2010 - beginning of 2011. Fixed exchange-rate regime created a threat of FX reserves depletion, and, in March 2011, the NBB imposed restrictions on the sale of foreign currency. In May 2011, the NBB finally devalued the national currency by 56% and allowed for the free-floating of the exchange rate at the interbank FX market. By October 2011, inflation had reached 74.5% (CPI growth rate in January-September) and the difference between the official and the market exchange rate had constituted around 60%. Money supply (money aggregate M2 in national currency) grew by 33%, while broad monetary base (M3) increased by 42% (NBB Statistics Database). In such conditions, the NBB faced the necessity to make cardinal changes to the monetary policy.

The undertaken measures in the second half of 2011, according to NBB (2012), included:

- Abandonment of public programs' financing via expansionary crediting.

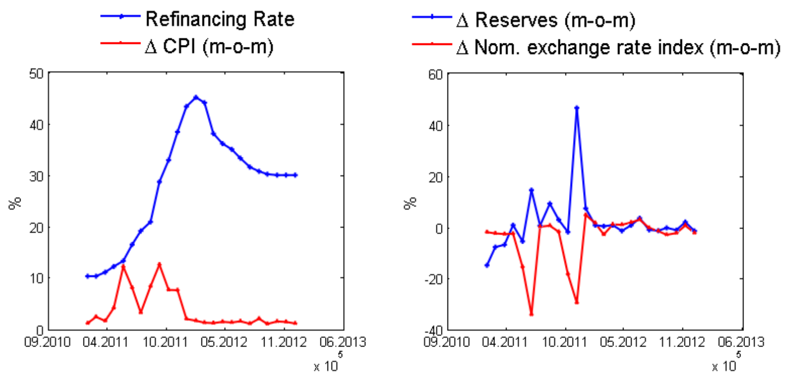
From June 1, 2011, refinancing of the Belarusian banks is allowed only through short-term conventional money market instruments.

- Ensuring positive real interest rate. This measure resulted in sharp increase of nominal interest rates in the second half of 2011: the refinancing rate increased from 10.5% (01.01.2011) to 45% (01.01.2012), while average interbank rates grew from 10.6% to 62.3%.

- Switching to floating exchange rate regime. As the result of abandoning soft peg in October 2011, the BYR dropped again by 52% from its official value. Meanwhile the NBB declared its determination to limit FX interventions and to rely on monetary policy instruments to guarantee stability of the exchange rate.

While defining the monetary policy for 2012 and 2013, the NBB formulated its main goal as lowering of inflation: to 19-22% in 2012 and to 12-15% in 2013. Another declared objective was to ensure sustainable amount of the international reserves (NBB 2011; 2012). The results of the policy measures are summarized in Figure 2.1.

Figure 2.1: Dynamics of the refinancing rate and monthly growth rates of the CPI, reserves, and nominal exchange rate index in 2011-2012, %



Source: NBB Statistics Database

N.B.: Exchange rate index represents units of foreign currency per 1 BYR. Its decrease means devaluation.

In 2012, annual inflation reached 21.8% and the real refinancing rate throughout the year was kept positive. Dynamics of the effective nominal exchange rate remained stable. Yet, some inconsistencies in the monetary policy are still present and may impede the macroeconomic stabilization in Belarus.

First, alongside the inflation target, the NBB has to put up with a goal of high output growth rate set by the government: 8.5% for 2013, which will be hard to achieve without expansionary policies. Already in the first half of 2012, the NBB started to progressively lower the policy rate, to reach an annual decrease of 13 percentage points (from 43% to 30%). During the first six months of 2013, the refinancing rate was decreased by another 6.5 percentage points. Another worrying signal is the recent increase of the real wages that has outpaced productivity growth. In 2012, the latter indicator made up 3.4%, while the growth rate of the real wages constituted 21.9% (NBB 2013).

Second, the positive effect of currency devaluation on net exports has already vanished, and the balance of payments has again experienced deterioration since Autumn 2012. The need to pay out debt, difficulties in attracting foreign capital, and the intention of the NBB to support the value of the BYR create additional pressure on the reserves amount and, consequently, on the exchange rate. Moreover, as an important argument against the current floating exchange rate regime, we should mention limitations of the Belarusian financial market and insufficient volumes of the FX operations with the BYR for proper hedging activities.

Inflation and depreciation expectations are still high: average annual interbank interest rates constituted 27.6% in December 2012 and increased to 35.3% in January 2013. The share of FX-denominated deposits, in the beginning of 2013, made up around 55% of the broad money supply (M3 aggregate); prior to the currency crisis in 2011, this indicator had fluctuated between 35-45%. Households' savings in the foreign currency represent more than 70% of all deposits (NBB Statistics Database).

In this context, discussions on the possible monetary union with Russia have rearisen. Some real effects of this arrangement look appealing: reduction of transaction costs should benefit Belarusian business, while potential decrease of uncertainty and improved access to foreign capital could facilitate the conduct of structural reforms and renovation of enterprises. Positive monetary effect may result from importing presumably tighter policy of the CBR. Close trade links between the countries and long history of economic integration that has intensified with the establishment of the Common Economic Area (January 2012) shall contribute to the success of such arrangement. From another side, abandonment of the independent monetary policy will bring about loss of shock-absorbing instruments (interest and exchange rate). Other losses may arise due to larger vulnerability to external shocks, some increase of the price level, and possible political and social tensions. The extent of these costs depends on many criteria. However, the objective of the present thesis is to evaluate the costs that may arise due to misalignment of the Belarusian and Russian economies. Consequent sections address the following hypotheses:

1. Despite long-dated history of integration, there is significant cyclical and structural misalignment between the Belarusian and Russian economies due to asymmetry of shocks and different specializations.
2. There are substantial differences between current monetary policy responses to shocks in Belarus and Russia and their transmission mechanisms.
3. Welfare losses for the Belarusian economy associated with the possible monetary union will be higher than those implied by the inflation targeting regime and the effective monetary policy rule.

In case of significant misalignment in terms of sources and responses to shocks, Belarus is likely to bear high costs of the monetary union, since the single policy would not be efficient in addressing country-specific fluctuations or would result in undesired feedback.

2.2 Optimum Currency Areas: Theory and Empirics

To verify the aforestated hypotheses, we apply empirical frameworks based on the Optimum Currency Area (OCA) theory. The OCA approach helps to evaluate possible benefits and costs of monetary integration and, hence, to determine whether countries of interest constitute an optimum one-currency region. Comprehensive literature surveys on the OCA are presented in Mongelli (2002), Dellas & Tavlas (2009), and Grauwe (2012).

Mundell (1961) laid the basis of the theory by formulating and providing an intuitive answer to a question "what is optimum currency area?" The proposed definition of an OCA is simply 'a domain within which the exchange rate is fixed'; optimality of such domain, according to Mundell, depends on internal factor mobility that could facilitate adjustment to shocks. McKinnon (1963) and Kenen (1969), followed by other researches, made further contributions by identifying possible benefits and costs of monetary integration and elaborating on the optimality criteria of the OCA. As a summary of the OCA theoretical literature, Table 2.1 presents possible costs and benefits of monetary integration for a country that gives up its own monetary policy by either adopting some common legal tender or anchoring to another country's currency. Here and further in the text, the term "monetary integration" is employed in broad sense and encompasses various types of the hard peg.

Table 2.1: Benefits and costs of the monetary integration

Benefits	*Costs*
• Elimination of transaction costs; • Reduction of exchange rate variability and corresponding risks; • Reduction of barriers to financial integration and better access to international financial markets; • Creation of more favorable investment environment; • Prevention of the inflationary bias of the monetary authorities; lowering of inflation rates.	• Direct costs of losing seignorage income and of legal procedures needed to frame the new monetary arrangement; • Loss of independent monetary policy, and thus, of specific tools (exchange rate and interest rate) used to facilitate the economy's adjustment to shocks; • Larger effects of real domestic shocks (higher variability of output and consumption); • Larger vulnerability to external real, monetary, and financial shocks; • Likely increase of the public debt in case of the current account imbalances and low competitiveness of an entering country (Greek problem).

Source: based on Grauwe (2012), Volz (2010), Mongelli (2002)

Given the benefits and costs of monetary integration, the next step in the OCA analysis is to identify a number of criteria a country has to meet in order to minimize costs of abandoning its own monetary policy and, from another side, in order to profit to a larger extent from the common-currency benefits. Mongelli (2002) defines the OCA criteria as properties that reduce the efficiency of nominal exchange rate adjustments relative to what could be achieved by a single monetary policy and alternative stabilization mechanisms. An important contribution of the early OCA studies was to identify such core properties. Mundell (1961) named factor mobility and incidence of common shocks as critical determinants for the design of one-currency areas. McKinnon (1963) emphasized the importance of an economy's openness to its potential common-currency partners; while Kenen (1969) discussed advantages of fiscal integration and argued that diversification of production and consumption within probable members of a currency union should reduce likelihood of asymmetric shocks. Mundell (1973) pointed that financial market integration and international risk sharing could compensate for idiosyncratic shocks within a currency union. Other commonly cited OCA criteria include: flexibility of wages and prices, similarity of economies' structures, convergence of price levels, inflation, and interest rates, credibility of the common monetary authority. With the development of the OCA theory, the so called meta-criteria were formulated, such as synchronization of shocks and alignment of policy responses.

A theoretical framework for evaluation of real and monetary effects of currency unions is provided, for instance, in Alesina & Barro (2002). According to the proposed model, a positive real effect of a currency union is related to reduction of trading costs and better distribution of resources between involved countries, while monetary effects may be both positive and negative. Costs arise from the loss of independent monetary policy that generates country-specific responses to shocks. Meanwhile, a country with uncommitted monetary authorities may benefit from anchoring to a state that features credible policy rules. The authors showed that optimality of a currency union depends on size of countries, trade links between them, and shock synchronization. Alesina and Barro concluded that a typical country to have the strongest incentive to join a currency union is a small open economy with a history of high inflation that is close (in a variaty of ways) to a large and monetary-stable potential anchor.

The stream of empirical literature on the OCA has developed primarily alongside the economic and monetary integration processes in Europe. Later, the methods elaborated within the OCA theory were applied to study integration prospects in other regions: the Latin American and Asian countries (Larrain & Tavares 2003; Volz 2010), Africa (Houssa 2008). Many early studies provided general cost and benefit analysis of the possible monetary integration using simple criteria (such as trade openness, similarity of economies' structures) and basic alignment indicators. Later empirical works focused on deeper analysis of specific OCA properties: price and wage flexibility (Blanchard & Wolfers 1999), labor and financial market integration (Decressin & Fatas 1995; Crucini & Hess 1999), price level and inflation rate convergence (Cihak & Holub 2005), fiscal integration (Mongelli & Bandt 2000), etc. The studies of meta-criteria such as shock similarity developed in 1990s. Bayoumi & Eichengreen (1996) extended a SVAR approach developed by Blanchard & Quah (1989) to analyze incidence of demand and supply shocks across the European economies. Despite many limitations, estimating synchronization of shocks has become a common part of the OCA analysis, as it is believed to summarize economic and financial alignment of the countries. Similarity of the policy responses to shocks and their transmission provides a complementing insight on the convergence of economies. VAR models have been conventionally used to investigate alignment of monetary policies within a (perspective) one-currency area. Relevant empirical studies are reviewed in more detail in Subsection 4.1.2. One of the recent developments in the OCA empirical studies has been application of the New-Keynesian models. This framework accounts for micro foundations and sets explicit welfare criteria for the monetary policy regimes. To some extent, it also overcomes the Lucas critique. As a recent example, Ajevskis & Vitola (2011) estimated a small open economy NK DSGE model for seven EU countries, non-members of the euro area, in order to compare implications of the inflation-targeting versus fixed exchange-rate regime.

Costs and benefits of possible monetary integration between Belarus and Russia had received some attention following the signing of the Treaty on the Creation of the Union State (1999) and adoption of the Joint Action Plan for the introduction of a common monetary unit (2002). Prokopenko *et al.* (2004) qualitatively investigated whether Belarus and Russia fulfill some OCA criteria (in particular, convergence of structural indicators, correlation of output gaps, and availability of other adjustment mechanisms) and discussed implementation issues of the possible monetary union. In addition to commonly accepted criteria, the authors compared levels of economic restructuring and liberalization. The study concluded that the adequate base for an operating currency union was yet to be established and that the long-term effects of monetary integration for Belarus were not clear. Kallaur (2001) and Tereshenko (2002b;a) provided quantitative analysis of whether Belarus and Russia met various OCA criteria and elaborated on the possible implications of the monetary union. Using the framework outlined in Bayoumi & Eichengreen (1998), Tereshenko (2002a) analyzed exchange market pressure and reported absense of significant shock correlation between the Belarusian and Russian economies. Cernookij (2005) applied the Blanchard and Quah (1989) procedure on the quarterly data (1996-2003) and found that both demand and supply shocks in Belarus and Russia were asymmetric. Overall conclusion from the studies conducted in 2002-2006 was that Belarus and Russia did not constitute an OCA. Following the establishment of the Common Economic Area between Russia, Belarus, and Kazakhstan, Luzgina (2012) qualitatively examined convergence of some economic variables in Russia and Belarus in 2000-2010. The paper (although lacking rigorous justifications) concluded on undesirability of the monetary union between the countries.

The present thesis provides several quantitative measures of alignment between Belarus and Russia. The analyzed time-series encompass quarterly and monthly data from 2000 to 2012, thus, including the periods of the financial crisis in 2008-2009 and the balance-of-payments crisis in Belarus in 2011. In this way, the work contributes to the empirical applications of the OCA theory and to the studies of the Belarusian and Russian integration.

2.3 Convergence of the Russian and the Belarusian Economies: Qualitative Analysis

The section presents a qualitative analysis of some real and nominal variables, thus, giving a preliminary insight on the alignment between the Belarusian and Russian economies and fulfillment of some OCA criteria. Table 2.2 highlights basic data on Russia and Belarus.

Table 2.2: Russia and Belarus: Basic data, 2012

Indicator	**Belarus**	**Russia**	**Belarus as % of Russia**
Population, mln	9.7	141.9	6.8%
Size, thousand sq km	207.6	17075	1.2%
GDP, mlrd USD (current prices)	63.1	2053	3.1%
GDP per cap., USD PPP (constant prices, 2005)	13427	15177	88%
Bilateral Trade Turnover (% of total trade)	45.2%	4.4%	—

Source: The World Bank DataBank, bilateral Balance of Payments (NBB Statistics Database).

The data suggests asymmetry of the possible monetary union. With Russia being the dominant partner, Belarus has low opportunities to influence the common monetary policy in case of individual shocks. Therefore, the degree of alignment between the economies (dependent on the presence of the OCA criteria) will determine whether single monetary policy, conducted mostly in the interests of Russia, can be also acceptable for Belarus.

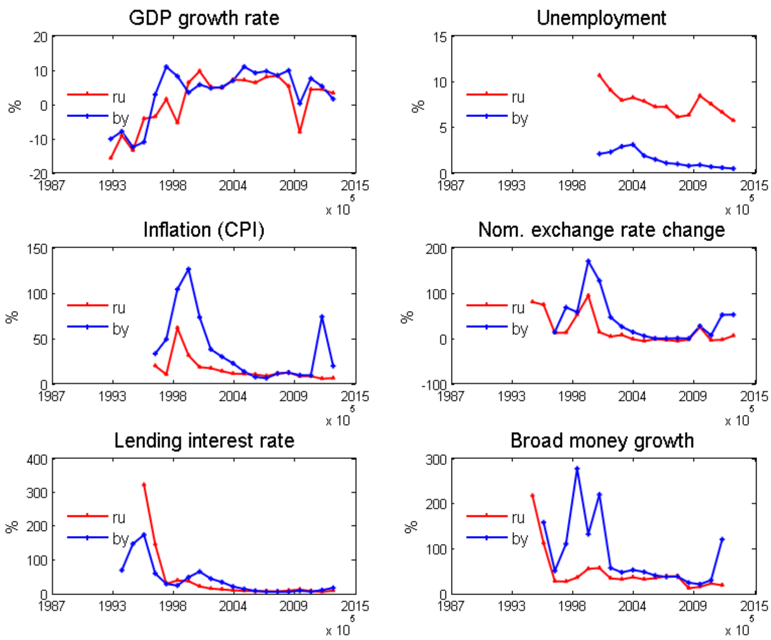
Openness of an economy is one of the critical factors in the cost and benefit analysis of a possible monetary union with country's trading partner(s). As a rule, the more open a country is, the more likely it is that the benefits will outweigh the costs. Trade turnover with Russia (as of 2012, Balance of Payments, NBB Statistics Database) made up 72% of the Belarusian GDP or 45.2% of the total trade. Exports to Russia constituted 34% of the total Belarusian exports, while imports featured a 57.1% share. From one side, these figures promise big potential for reduction of transaction costs in case of the monetary union; also one may expect high degree of shock synchronization. From another side, trade imbalance takes place: the trade deficit with Russia as of 2012 constituted 16.3% of the Belarusian GDP. Besides, structural misalignment in trade is present: mineral products compose more than 60% of the Belarusian imports from Russia, while agriculture and food items, vehicles, and equipment prevail among exports to Russia.

Figure 2.2 illustrates annual dynamics of the key macroeconomic indicators: real GDP growth rates, unemployment rates, CPI inflation, exchange rate to USD change, and average lending interest rates.

The annual growth rates of the real GDP have had similar patterns, with the Belarusian economy growing, in general, at a slightly higher speed. The unemployment figures are not very representative as the Belarusian statistical office reports only the share of registered unemployed people; this indicator may underestimate by 3-4 times the unemployment rate defined in compliance with the International Labor Organization (ILO) methodology. Despite this bias, comparison of the variables shows that the economic policies of the Belarusian authorities are focused on preserving low unemployment. For instance, the number of registered unemployed people increased imperceptibly during 2008-2009 crisis in Belarus.

As to the nominal variables, there had been high convergence of inflation rates in 2004-2010 as the NBB implemented soft-peg regime with relatively slim fluctuation band. The movements of the nominal official exchange rates (relative to the USD) had been visually symmetric, including devaluation in 2009 of both the RUR and the BYR. Consequently, the average lending interest rates had converged; despite higher inflation, in 2009-2010 lending rates in Belarus

Figure 2.2: Dynamics of the key macroeconomic indicators in Belarus and Russia, %



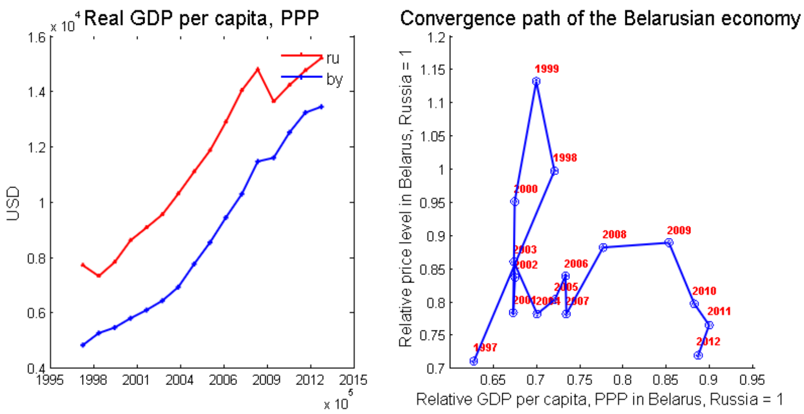
Source: The World Bank DataBank.

N.B. Here, nominal exchange rate is an official average exchange rate (Local currency per 1 USD) for a given year.

were lower than in Russia, what can indicate discount financing. However, since 2008, Belarus had featured higher money supply growth rate, which (given the attempt to stabilize inflation using the soft-peg regime under current account deficit) had contributed to the creation of imbalances in the economy.

Figure 2.3 illustrates development of real GDP per capita (at Purchasing Power Parity (PPP)) and relative price levels in Belarus and Russia.

Figure 2.3: Real convergence of the Belarusian and Russian economies



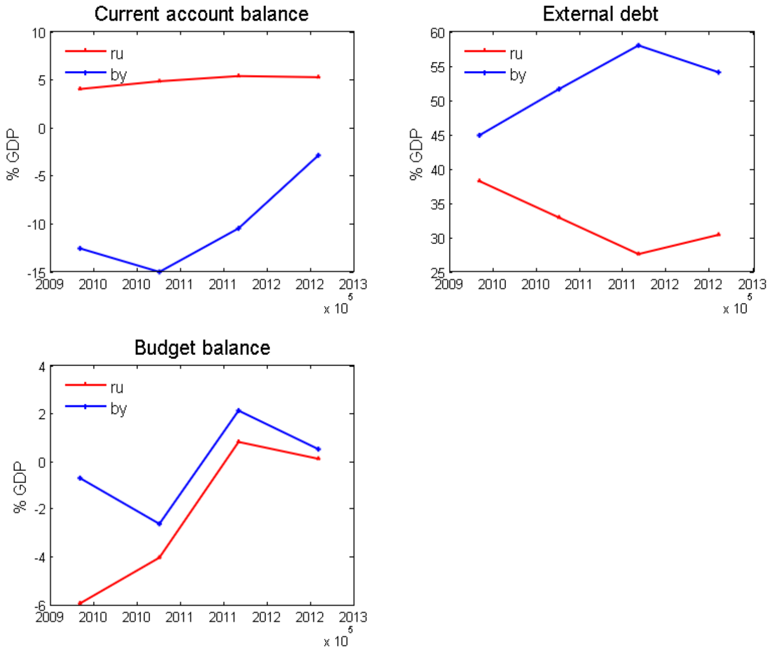
Source: The World Bank DataBank, own calculations.

Both Russia and Belarus belong to the group of upper middle income countries with about the same level of the GDP per capita. There has been slightly higher convergence in terms of this indicator since 2009, as Russia had apparently experienced sharper economic decline. The relative price level was calculated using the PPP conversion factor (GDP based) to market exchange rate ratio. The price level in Belarus had constituted around 80-88% of the Russian indicator with some signs of convergence before the crisis in 2008-2009. The price level differential has started to increase since 2010 (due to loss of the BYR purchasing power relative to the USD), and in 2012 was almost at the level of 1997.

As to the average monthly wages (expressed in USD), after slight recovery in 2012, the Belarusian wages still make up only about 52% of the Russian nominal average earnings or about 71% at the PPP. Hence, before entering the monetary union with Russia, Belarus should undergo real convergence in terms of price levels and wages. Otherwise, in the absence of exchange-rate adjustment channel, real convergence may result in higher inflation and real interest rates differentials, thus, impeding the efficiency of the single monetary policy.

Figure 2.4 depicts fiscal and foreign positions of Belarus and Russia.

Figure 2.4: Fiscal and foreign positions of Belarus and Russia



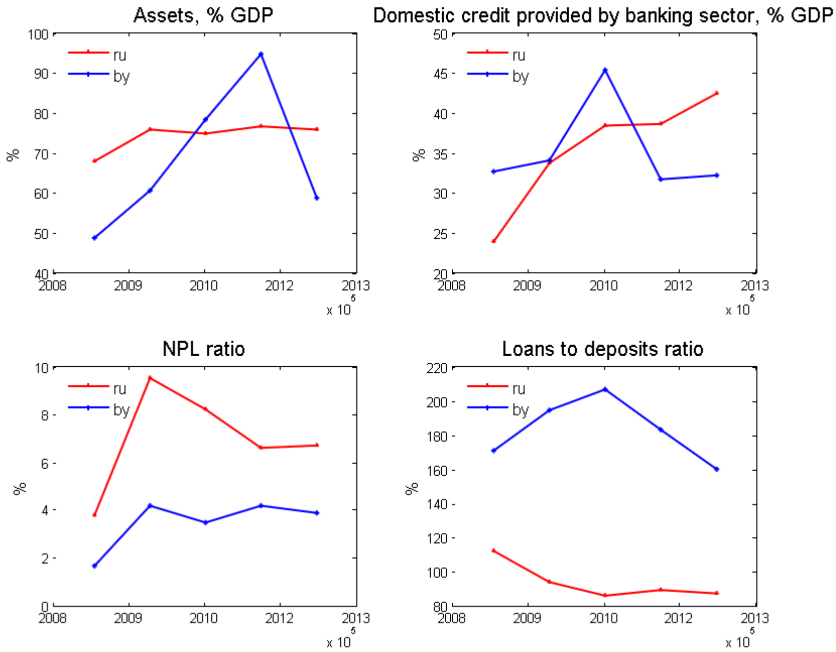
Source: EBRD Economic Data.

Regarding the fiscal position, the budgets have been, in general, balanced in both countries with fiscal deficits present only in 2009 and 2010 (reached maximums: -5.9% in Russia in 2009 and -2.6% in Belarus in 2010). However, from 2008, misalignment of the public debt indicators has increased. Debt of the Belarusian central government (both domestic and foreign) grew in 2008-2009 to almost 20% of the GDP with the issuance of the government Eurobonds.

As to the foreign position, the current account surplus is characteristic for the Russian economy, while the contrary holds for Belarus. Following devaluation of the BYR in 2011, the current account position improved to some extent in 2012 (the deficit reduced to 3% of the GDP); however, the current account deficit with Russia in 2012 remained above 20%.

Some financial and banking sector indicators are presented in Figure 2.5. Since 2004-2005 the banking sectors in Russia and Belarus have become more aligned in terms of their weight in the economy (assets to GDP ratio, domestic credit to GDP ratio), concentration and overall performance. In both Belarus and Russia, state-owned banks have the largest market shares (50% of total assets in Russia and 66% in Belarus), while five largest banks control more than 50% of the market. The Belarusian banking sector has to rely more on external sources of financing (as the amount of loans surpasses that of deposits;

Figure 2.5: Financial and banking sector indicators of Belarus and Russia



Source: The World Bank DataBank.

however, due to stricter credit policy in 2011-2012, the loan-to-deposit ratio has had a tendency to decrease). Foreign banks account for 32.6% of total assets in Belarus. The market share of the Russian banks is estimated at 25% of total assets (NBB 2013). Thus, some transmission of the CBR monetary policy has already taken place through the credit channel.

The EBRD transition indicators provide an additional insight on the alignment of the economies (Table 2.3).

The pace of transition reforms in Belarus has been slower than in Russia, although some progress has been recently done concerning improvement of the business environment (taxation, registration, and licensing of business). Yet, higher share of state-owned enterprises, insufficiently liberalized prices and labor market, and regulated financial sector are likely to complicate transmission of the single monetary policy and to limit shock-absorption capabilities of other mechanisms (such as prices, wages, and capital mobility). From another side, further integration with Russia could contribute to faster institutional and structural changes in Belarus.

The results of the qualitative analysis provide ambiguous conclusions on alignment of the economies. Several observations suggest that high costs of

Table 2.3: EBRD Transformation indicators, 2012

*Indicator**	**Belarus**	**Russia**
Large scale privatisation	1.7	3.0
Small scale privatisation	2.3	4.0
Enterprise restructuring	1.7	2.3
Price liberalisation	3.0	4.0
Trade and FX system	2.3	4.0
Competition policy	2.0	2.7
Financial sector transformation	2	2.7

Source: EBRD Economic Data.
*1 represents little or no change from a rigid centrally planned economy and 4+ represents the standards of an industrialized market economy.

the monetary union are unlikely for Belarus, among them: openness of Belarus relative to Russia, general convergence in terms of output growth rates, similar income levels, balanced budget, and ownership links in the banking sector. From another side, trade imbalances and current account deficit with Russia are present, as well as discrepancies in price levels and wages. Belarus is gradually converging to the Russian economy, which may be accomplished more efficiently under flexible exchange-rate regime. Different paces of market reforms and remaining rigidities in both economies may increase costs of fixing the exchange rate to the RUR.

Chapter 3

Shock Synchronization and Structural Alignment of the Economies

Synchronization of business cycles within a common currency area is usually referred to as one of the most important OCA criteria. Once fluctuations of the member-economies are symmetric, the single monetary policy may be sufficient to facilitate stabilization in each particular country. Hence, the relative costs associated with the loss of independent monetary policy are reduced. This chapter analyses symmetry of the business cycles in Russia and Belarus by focusing on the sources of the fluctuations. Section 3.1 features preliminary analysis based on simple correlation measures between some indicators of economic activity. Section 3.2 presents estimated correlations of demand and supply shocks recovered from a structural VAR model. Section 3.3 analyses indicators of the structural alignment of Russia and Belarus.

3.1 Cyclical Correlations

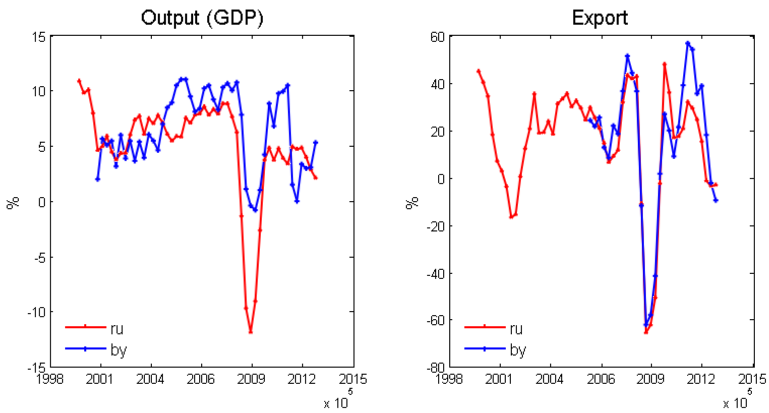
First, we perform correlation analysis of several economic activity indicators to obtain a general view on the cyclical alignment of the Belarusian and Russian economies. Simple correlation coefficients are calculated:

$$r_{xy} = \frac{cov_{xy}}{\sqrt{\sigma_x^2 \sigma_y^2}},$$

where cov_{xy} stands for covariance between series x and y; σ_x and σ_y represent standard deviations of the series. To follow dynamics, we use rolling correlation coefficients. The moving time window for a given observation (quarter) is defined as 11 preceding quarters plus the observation itself.

The coefficients are calculated for the growth rates of real GDP and export volumes. The series are taken on quarterly basis and cover the period from 2000:Q1 to 2012:Q4 (52 observations). The data is obtained from the National statistical offices and the central banks of Belarus and Russia. Prior to the analysis, the time-series were log-transformed to account for the exponential growth. Growth rates were calculated using two approaches: 1)year-on-year (seasonal) differences were applied to the original series; 2) quarter-on-quarter differences were taken for the seasonally adjusted series. Seasonal adjustment was conducted using X-12-Arima package, available in Gretl. Figure 3.1 represents the alignment of the economic activity indicators.

Figure 3.1: Dynamics of the economic activity indicators, original series, y-o-y changes, %



Source: National Statistical Committee of the Republic of Belarus, Federal State Statistics Service of the Russian Federation.

Table 3.1 contains correlation coefficients of economic activity indicators for the whole analyzed period (with lower and upper boundaries at 95% confidence level). It also shows probability of accepting the null hypothesis of no correlation between the series.

Correlation indicators suggest high degree of the economic activity alignment in Belarus and Russia. In particular, export growth rates are strongly synchronized. Vertical integration of the economies (from the Soviet times) may be behind the obtained numbers.

Figure 3.2 depicts evolution of rolling correlation coefficients calculated over

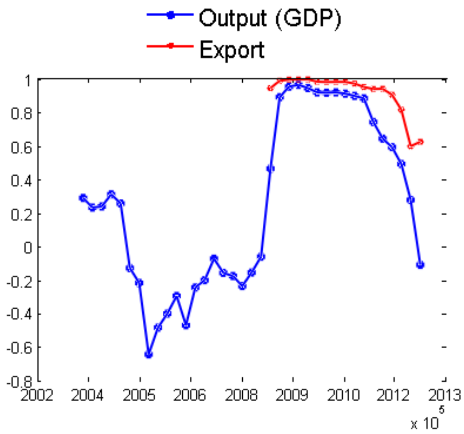
Table 3.1: Correlation coefficients of the economic activity indicators

Indicator	**Coefficient**	**pValue**	**Lower B.**	**Upper B.**
GDP (y-o-y)	[0.6068]	[0]	[0.3899]	[0.7599]
Exports (y-o-y)	[0.9285]	[0]	[0.8497]	[0.9667]
GDP (q-o-q)	[0.3469]	[0.0126]	[0.0789]	[0.5682]
Exports (q-o-q)	[0.8610]	[0]	[0.7292]	[0.9313]

Source: own calculations.

3-year windows. The strongest symmetry is observed in the years 2005-2009

Figure 3.2: Rolling correlations of the economic activity indicators, original series, y-o-y changes, %



Source: own calculations.
3-year (12 quarters) rolling windows.

that featured relatively favorable economic conditions for both countries. Increasing synchronization of the economies' growth rates in that period also reflects convergence achieved following the establishment of the Union State. Since 2008, though, the integration process had slowed down. Moreover, different after-crisis recovery paths contributed to the increasing misalignment of the economies. Stabilization policies in Belarus in 2009-2010 focused primarily on mitigating short-term effects of the crisis and resulted in the new downturn in 2011. It may also be true that convergence in 2005-2008 was not based on fundamentals, rather due to the general economic upturn. Table 3.2 contains correlation coefficients calculated for two separate sub-samples: 2000:Q1-2009:Q4 and 2010:Q1-2012:Q4. The choice of the threshold is based on the observation of the rolling correlations (2010:Q1 features decrease of correlation coefficients for both indicators of economic activity). In addition, three preceding quarters had been marked by a number of anti-crisis actions by the Belarusian authorities, such as devaluation of the BYR, change in the currency peg, and attraction of foreign loans.

Table 3.2: Correlation coefficients of the economic activity indicators: sub-samples

2001:Q1 - 2009:Q4				
Indicator	**Coefficient**	**pValue**	**Lower B.**	**Upper B.**
GDP (y-o-y)	[0.7072]	[0]	[0.4971]	[0.8390]
Exports (y-o-y)	[0.9778]	[0]	[0.9379]	[0.9921]
GDP (q-o-q)	[0.4100]	[0.0086]	[0.1129]	[0.6398]
Exports (q-o-q)	[0.9170]	[0]	[0.7985]	[0.9671]

2010:Q1 - 2012:Q4				
Indicator	**Coefficient**	**pValue**	**Lower B.**	**Upper B.**
GDP (y-o-y)	[-0.1066]	[0.7416]	[-0.6413]	[0.4978]
Exports (y-o-y)	[0.6226]	[0.0306]	[0.0757]	[0.8815]
GDP (q-o-q)	[-0.2085]	[0.5156]	[-0.6988]	[0.4151]
Exports (q-o-q)	[0.5932]	[0.0420]	[0.0293]	[0.8707]

Source: own calculations.

We use output gap as additional proxy of economic activity. Output gap is obtained by extracting the cyclical component of the seasonally-adjusted GDP time-series with Hodrick-Prescott (further, HP) filter ($\lambda = 1600$ for quarterly observations). Table 3.3 shows correlation coefficients, calculated for the whole period and 2 subsamples.

Table 3.3: Correlation coefficients of the output gaps

Indicator	**Coefficient**	**pValue**	**Lower B.**	**Upper B.**
2001:Q1-2012:Q4	[0.6064]	[0]	[0.3997]	[0.7545]
2001:Q2-2009:Q4	[0.7260]	[0]	[0.5386]	[0.8449]
2010:Q1-2012:Q4	[-0.3352]	[0.2869]	[-0.7624]	[0.2956]

Source: own calculations.

The conclusions are in line with the previous analysis: correlation coefficients of the output gaps are close to those obtained for the year-on-year GDP growth rates. In general, we witness some alignment in the economies' business cycles, mostly, because the countries are subject to common external shocks; different responses to fluctuations might be the major sources of growing misalignment since 2010.

When using the EU countries as benchmarks (CNB 2012), the correlation between economic activity indicators in Belarus and Russia is comparable, for example, to the alignment of Poland and Slovakia with the EU as a whole. Yet, if most EU countries featured increase in correlation coefficients as the result of the 2008-2009 crisis, in the Russian-Belarusian case, the crisis led to the opposite effect.

3.2 Synchronization of Shocks

3.2.1 Methodology

Since macroeconomic variables hardly respond in the same way to all types of shocks, it might be of use to distinguish between various types and origins of disturbances. It is common to differentiate between shocks that temporarily affect the economy (demand shocks) and those that have long-term impact (supply shocks, which can be also interpreted as productivity gains/losses). Blanchard & Quah (1989) proposed a feasible procedure to decompose the observed shocks into supply and demand disturbances. This approach has been followed by other researches in their empirical studies on the OCA (Babetskii 2005; Volz 2010, see, for example,). Within the OCA analysis, the treatment of demand and supply shocks is not uniform regarding their contribution to the costs of monetary integration. Some argue (Grauwe 2012) that, since demand shocks often result from country-specific monetary policies, their significance will automatically decrease with the introduction of a common currency, and, hence, asymmetry of demand shocks is not critical for evaluation of the possible costs. Other researchers argue that symmetry of demand disturbances is, on the contrary, important; the economies sharing, for instance, external demand shocks, are likely to be cyclically aligned. Babetskii *et al.* (2004) mention that misalignment in terms of supply shocks is not necessarily problematic, since it may be ”simply” translated into inflation differentials. We will refrain from discussing relative importance of demand and supply shocks' symmetry for the costs of the monetary union and, within the scope of this work, will rather concentrate on estimation of their general alignment.

Blanchard & Quah (1989) proposed a procedure to decompose observed shocks to output and unemployment into two types of underlying disturbances: supply and demand. For the needs of the OCA analysis, correlation coefficients are then computed separately for the recovered supply and demand shocks. It has been a common practice to use GDP as output indicator and price index (either GDP deflator or CPI) as additional macroeconomic variable. The algorithm of applying Blanchard and Quah decomposition is presented below.

1. Two types of disturbances (supply and demand) are assumed to affect output and price level. Supply shocks have long-term effect on output level, while demand shocks' impact is short-term. It is also assumed that both shocks have permanent effect on price level (or temporary effect on inflation - with co-movement during demand shocks and opposite reaction of output and inflation to supply shocks).

Table 3.4: Reaction of output and prices to the aggregate shocks

Indicator	**Shock**	**SR**	**LR**
Output	positive AS	positive	positive
	positive AD	positive	zero
Price level	positive AS	negative	negative
	positive AD	positive	positive

Source: Blanchard & Quah (1989)

2. Joint process of output growth rates and inflation is constructed using Wold decomposition. Both output growth rate and inflation are represented as infinite sums of supply and demand shocks.

$$X(t) = \sum_{j=0}^{\infty} A(j)e(t-j) \tag{3.1}$$

where
$X(t) = [\triangle\, y(t)\ \pi(t)]'$; $\triangle\, y(t)$ - output growth rate; $\pi(t)$ - inflation rate;
$e(t) = [e_d(t)\ e_s(t)]'$; $e_d(t)$ - demand shock; $e_s(t)$ - supply shock;
variance of structural disturbances is constant and normalized to 1 for convenience; it is assumed that demand and supply shocks are not correlated: $covar(e_d, e_s) = 0$;

$A(t)$ - matrix of response coefficients to structural shocks at lag t:

$$A(t) = \begin{vmatrix} a_{11}(t) & a_{12}(t) \\ a_{21}(t) & a_{22}(t) \end{vmatrix}.$$

3. Usual VAR (in reduced-form) is estimated. It can be also represented as indefinite moving average process (3.2).

$$X(t) = \sum_{j=0}^{\infty} B(j)u(t-j) \tag{3.2}$$

where
$u(t) = [u_y(t)u_\pi(t)]'$; $u_y(t)$ - observed shock to output; $u_\pi(t)$ - observed shock to inflation; $var(u) = \Omega$.
$B(t)$ - matrix of estimated response coefficients to observed shocks at lag t:

$$B(t) = \begin{vmatrix} b_{11}(t) & b_{12}(t) \\ b_{21}(t) & b_{22}(t) \end{vmatrix}.$$

The innovations (observed shocks) are linear combinations of underlying supply and demand disturbances (3.3).

$$\begin{vmatrix} u_y(t) \\ u_\pi(t) \end{vmatrix} = \begin{vmatrix} a_{11}(0) & a_{12}(0) \\ a_{21}(0) & a_{22}(0) \end{vmatrix} * \begin{vmatrix} e_d(t) \\ e_s(t) \end{vmatrix} \tag{3.3}$$

4. In order to recover underlying supply and demand shocks, four restrictions should be imposed. The first three restrictions follow from the relation between innovations in the reduced-form VAR and underlying demand and supply shocks. It can be shown that $A(0)A(0)' = \Omega$; consequently
$var(u_y) = a_{11}(0)^2 + a_{12}(0)^2$;
$var(u_\pi) = a_{21}(0)^2 + a_{22}(0)^2$;
$covar(u_y, u_\pi) = a_{11}(0)a_{21}(0) + a_{12}(0)a_{22}(0)$;

The fourth restriction follows from the definition of the demand shock that is assumed to have only temporary impact on the output, i.e. its cumulative effect on output growth rates should sum up to zero: $\sum_{j=0}^{\infty} a_{11}(j) = 0$. Hence,
$[1 - \sum_{j=0}^{\infty} b_{22}(j)]a_{11}(0) + \sum_{j=0}^{\infty} b_{12}(j)a_{21}(0) = 0$.

5. Having obtained the coefficients, one can recover structural supply and demand shocks and measure their correlation.

In order to apply Blanchard and Quah procedure both series should be stationary. Blanchard and Quah solve the problem by removing the time-trend from the unemployment series and by allowing for a structural break in the output growth rates. Alternative approach is to check the series for cointegration and if the latter is present, to estimate a Vector Error Correction Model (VECM). However, in the case of a two-variable model, this approach features a caveat (overidentification), in a way that if one variable has a long-run zero restriction, the other (due to cointegration) has to possess it as well.

3.2.2 Data

For the purpose of analysis, following datasets were used for both countries: real GDP (as proxy of output) and the CPI (as primary inflation measure). As an alternative inflation measure, we use the Producer Price Index (PPI). The data was taken on a quarterly basis, spanning from 2000Q1 to 2012Q4. The time-series were log-transformed and growth rates were calculated using year-on-year (seasonal) differences.

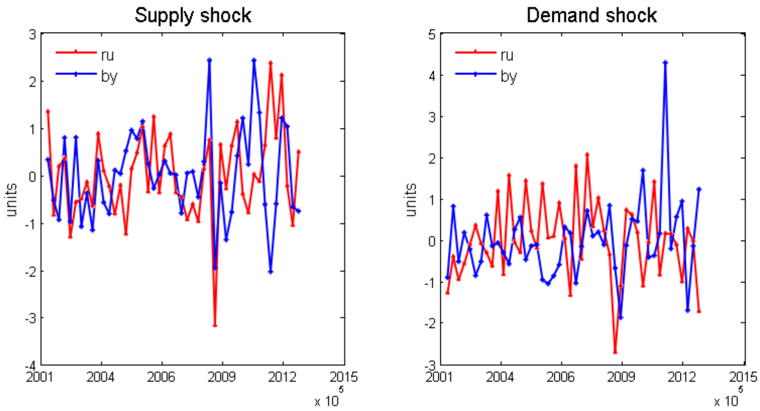
The variables were checked for stationarity using Augmented Dickey-Fuller Test. Output growth rates and inflation indicators were reported to be stationary for Russia at 10% confidence level and non-stationary for Belarus. We adopt the Blanchard and Quah approach and, prior to VAR estimation, perform some transformations of the series. Both Russia and Belarus, as countries in transition, have been subject to structural breaks and gradual macroeconomic stabilization, which, if not accounted for, could distort the results.

The series were stationarized in the following way. Output growth rates (both countries) were demeaned for Russia and detrended for Belarus; a structural break was allowed in 2008(Q4) for both countries. The threshold was selected based on the best fit of the deterministic part. Inflation series (both CPI and PPI) were transformed by removing the time-trend and, additionally for Belarus, by setting a structural break in 2011(Q2), when the BYR was devalued.

3.2.3 Results

The best-fit model (based on the information criteria and residuals' characteristics) was a two-lag VAR with the CPI as inflation measure. Further in the section, we refer to the results obtained for this specification. Figure 3.3 represents the plots of extracted demand and supply shocks, while Table 3.5 shows the calculated correlations.

Figure 3.3: Extracted demand and supply shocks, units



Source: own calculations.

Table 3.5: Correlation coefficients of the demand and supply shocks

Indicator	**Coefficient**	**pValue**	**Lower B.**	**Upper B.**
2001:Q1 - 2012:Q4				
Demand	[-0.1101]	[0.4665]	[-0.3880]	[0.1862]
Supply	[0.2290]	[0.1258]	[-0.0656]	[0.4870]
2001:Q1 - 2009:Q4				
Demand	[0.0646]	[0.7124]	[-0.2746]	[0.3895]
Supply	[0.5096]	[0.0018]	[0.2124]	[0.7205]
2010:Q1 - 2012:Q4				
Demand	[-0.2734]	[0.3898]	[-0.7324]	[0.3564]
Supply	[-0.3198]	[0.3108]	[-0.7551]	[0.3112]

Source: own calculations.

By visual inspection of the Figure 3.3, we note that the shocks, extracted as demand, are unsynchronized, except for the period 2008-2009. The discrepancy increases since 2010 (Q2). If we qualify the after-crisis demand shocks as mostly policy-induced, we may support our previous proposition that Belarus and Russia featured different responses to the 2008-2009 financial crisis. Positive demand shock in 2010(Q2) may also reflect the expansionary monetary policy of the NBB aimed at stimulating internal demand. Supply shocks, on the contrary, seem to be relatively aligned, from 2005 up to the currency crisis in 2011.

The calculated coefficients complement the above conclusions. Positive significant correlations are found only for supply shocks in the first subsample (2000-2009), thus, suggesting higher symmetry between the long-term (real) fluctuations. The results might be surprising given high correlation of the economic activity indicators reported earlier in the chapter. Obtained lower cyclical alignment can be attributed to the detrending procedures. The correlation of the transformed GDP growth rates falls to 0.27 for the whole sample and to 0.39 for the 2001-2009 selection, what is more consistent with the figures obtained for the supply and demand shocks.

While analyzing the results, we should be aware of the possible caveats. First, stationarization of the series may have resulted in the loss of important information. Second, the shocks were supposed to be identified based on the persistence of their effects (temporary vs. long-term); however, given short length of the available samples, some demand shocks, may have been identified as supply disturbances due to their relatively large and prolonged effect on the economic activity. Third, limitations of the specified VAR do not allow differentiating between the sources of disturbances: i.e. foreign vs. domestic shocks or, especially, exogenous shocks vs. policy-induced impacts. A common negative demand shock in 2009 reflects the consequences of the external demand drop due to the financial crisis, while the later shocks are likely to be related to the policy impacts. In general, the results are consistent with those obtained in the previous section: alignment between the Russian and Belarusian economies was significant during 2005-2009, but has shrunk since 2010. Some complementary conclusions can be drawn. When accounted for the time trend in the output growth rates, the correlation of economic activity drops roughly from 60% to 30%. Long-term fluctuations (i.e. productivity changes or simply high-impact shocks) are more synchronized than the temporary disturbances, in particular, those related to the policy impacts.

3.3 Structural Alignment

We analyze structural alignment of the economies by estimating Landesmann structural index, Grubel-Lloyd intra-industry trade index, and evaluating ownership links between Belarus and Russia.

Landesmann structural index

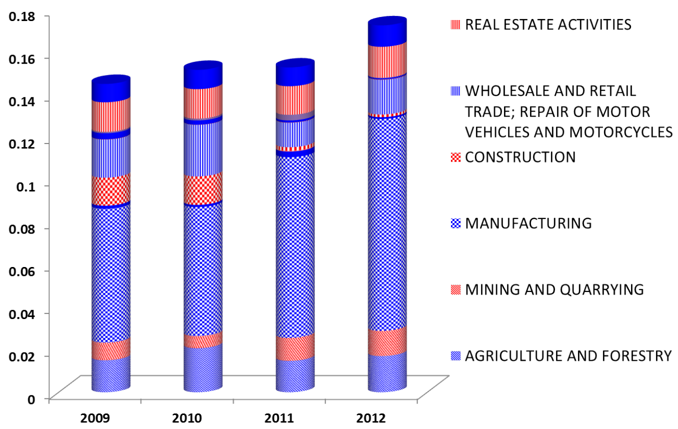
Incidence of asymmetric shocks also depends on structural differences between the economies. Sensitivity of firms to the monetary policy decisions differs across industries; consequently, structural (dis)similarity may have direct implications for the determination of the optimum currency area. Landesmann structural index characterizes contribution of different sectors to the total value added. When used to compare economy structures of two countries (A and B), it may be formally represented as:

$$LI = \sum_{i=1}^{n} \sqrt{(sh_A^i - sh_B^i)^2 * sh_A^i/100} \tag{3.4}$$

where sh^i stands for percentage share of the i-th sector in the value added of a country. The index can take values between 0 and 100. The closer it is to 0, the more symmetric are the structures of the countries of interest. The index is presented, for example, in CNB (2012) within the analysis of the Czech Republic's current alignment with the euro area. The obtained index (normalized to [0; 1] interval) increased from 0.15 (2006) to 0.2 (2011) and is interpreted as indicator of below-average structural similarity with the euro area (the index value for Germany, Austria, and Slovenia, for instance, does not surpass 0.1).

In order to calculate Landesmann index for comparison of the Belarusian and Russian industry structures, we analyze the annual GDP composition of the economies in 2009-2012. Industries are identified according to the first level of the ISIC (International Standard Industrial Classification of All Economic Activities) system. Figure 3.4 presents the values of the index in 2009-2012.

Figure 3.4: Landesmann structural index composition for Belarus/Russia in 2009-2012



Source: own calculations based on National Statistical Committee of the Republic of Belarus, Federal State Statistics Service of the Russian Federation data.

The structural difference between the Belarusian and Russian economies is comparable to that between the Czech Republic and the euro area. The major contribution to the index belongs to the manufacturing sector, which accounts for more than 30% of the Belarusian value added, while in Russia its share constitutes only 15%. Historically, Belarus has played the role of the manufacturing hub, and still a number of major enterprises (i.e. related to the oil industry) enter common production chains with the Russian suppliers of raw materials. From another side, such disparity may contribute to misalignments in the dynamics of exchange rates and terms of trade. Agriculture features the second largest share in the structural gap between the economies. In Belarus, this sector makes up more than 9% of the value added compared to only 3.5% in Russia. In addition, the Belarusian agricultural industry is heavily subsidized and regulated by the state and is characterized by low flexibility of prices and labor. Increase in the economy's structural misalignment (comparing 2009 and 2012) can be noted, mostly owing to the relative growth of the manufacturing in Belarus; some convergence, meanwhile, was achieved within the construction and retail trade sectors' shares.

Intra-industry trade

Another approach to compare structures of the economies is to analyze bilateral trade structure. Countries with a similar factor structure are likely to have high share of intra-industry trade in total turnover. The Grubel-Lloyd index serves as a quantitative measure of this characteristics. For an i-th product, the share of the intra-industry trade can be calculated as

$$GL_{i,t} = 1 - \frac{|X_{i,t} - M_{i,t}|}{X_{i,t} + M_{i,t}}, \tag{3.5}$$

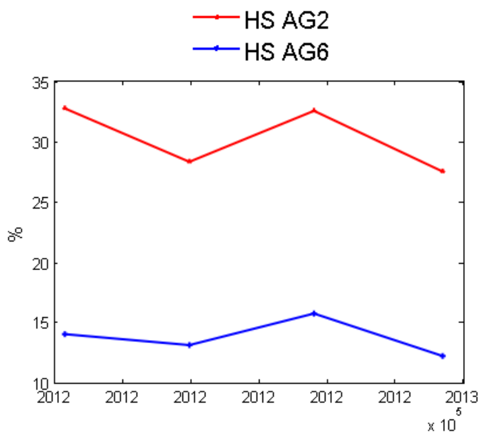
where $X_{i,t}$ - export of an i-th product and $M_{i,t}$ - import of an i-th product. The total share of the intra-industry trade in the total trade turnover may be then expressed as

$$GL_{i,t} = 1 - \frac{\sum_{i=1}^{n} |X_{i,t} - M_{i,t}|}{X_t + M_t}, \tag{3.6}$$

where $X_t + M_t$ represents total trade turnover in a given period. Application of this index for the OCA analysis can be also found in CNB (2012), where the Grubel-Lloyd index is calculated for the Czech Republic and several other EU-members relative to the euro area trade turnover. The obtained results (for 2010 data) range from 50% (Portugal) to 70% (the Czech Republic, Germany, and Austria) for the two-digit SITC breakdown and decrease to 25% (Slovenia) - 40% (the Czech Republic, Germany), when more detailed classification system (CN8) is considered.

To obtain the intra-industry trade share in the total trade turnover between Russia and Belarus, we consider bilateral trade statistics in 2008-2011. The sectors are classified according to the Harmonized System Codes (HS07). We calculate the index for two aggregation levels: AG2 (two-digit codes, breakdown in 99 sectors) and AG6 (six-digit codes). The calculated values are presented in Figure 3.5.

Figure 3.5: Grubel-Lloyd index (intra-industry share in the Belarusian/Russian trade turnover) in 2008-2011



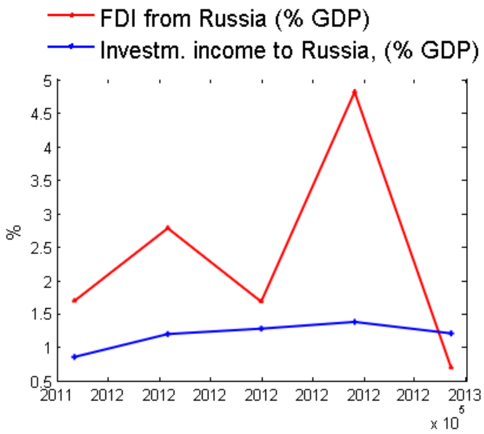
Source: own calculations based on UN Commodity Trade Statistics data

The share of the intra-industry trade between the countries is relatively low (when compared to the euro area level), due to the prevalence of the energy-related imports from Russia and limited production cooperation. Significant difference between the intra-industry values for two- and six-digit aggregation levels indicates that vertical integration dominates; horizontal trade (i.e. traded goods are of close nature/quality), which is characteristic for countries with similar economy structures, occupies a minor part of the bilateral trade turnover. Although, the Belarusian and Russian economies are integrated, the degree of specialization is high, what could contribute to higher costs of the possible monetary union.

Ownership links

We complete the analysis of structural alignment by considering the bilateral ownership links. We employ the Balance of Payments statistics on FDI inflows and investment income payments (Figure 3.6).

Figure 3.6: FDI inflows from Russia and investment income payments to Russia, % GDP



Source: Balance of Payments (NBB Statistics Database)

The ownership links between Russia and Belarus are strong relative to the rest of the world (NBB Statistics Database, National Statistical Committee of the Republic of Belarus). The annual FDI inflows from Russia made up about 30% of the total inward investments to Belarus in 2012; in 2009-2011, its share reached 70% of the FDI due to the operations involving Beltransgaz shares. The income investment payments to Russia constituted around 32-35% of the total investment income outflows in 2008-2012. The share of the Russian capital in the stock FDI also varied around 30% in 2008-2012. At the same time, relative to the GDP, the ownership links seem weaker: in 2012, with the stock FDI constituting only 2.5% of the Belarusian output, annual FDI inflows from and income payments to Russia amounted to around 1% of the output. For comparison, the share of the FDI from the euro area in the Czech GDP is around 50% (CNB 2012).

Summarizing the chapter, we cannot fully reject the hypothesis of significant cyclical and structural misalignment between the Belarusian and Russian economies. Correlation of the economic activity indicators over the analyzed period constitutes above 60%. Exports are the most synchronized with the correlation surpassing 90%. Yet, when accounted for the time-trend, correlation of the output growth rates falls to 30%; in addition, the economies' alignment has decreased since the beginning of 2010. We showed that temporary (demand) shocks were not symmetric, except for the recession period of 2008-2009, while the correlation of the long-term (supply) shocks constituted about 50% in 2000-2009, but has also declined in the recent years. We may, thus, conclude that origins of real and external demand shocks, hitting Belarus and Russia, are most likely to be common, however, the transmission of shocks and policy responses to them differ. Structural misalignment, low share of intra-industry trade, and still weak ownership links could also contribute to the increasing asymmetry in 2010-2012.

Chapter 4

Alignment of the Monetary Policies and Transmission Mechanisms

Alignment of the monetary policy can be considered as another "meta" OCA criteria (Mongelli 2002) that implies shock synchronization as well as similarity of the countries' economic and financial structures. Hence, comparison of the monetary policy and its transmission mechanisms is relevant from the perspective of the OCA analysis. First, discrepancy in the timing and the scope of the authorities' responses may indicate that the countries are subject to different shocks. Second, misalignment in the monetary policy transmission points on structural differences between the economies that result in disparate expectations of and reactions to the policy decisions. Additionally, a country suffering from inconsistent and weak actions of the monetary authorities may benefit if it adopts stricter monetary policy of the anchor-country. In this chapter, we use two approaches to compare the monetary policies in Russia and Belarus. First, we estimate monetary policy rules of the CBR and the NBB in order to compare their cyclicality and focus. Second, we evaluate monetary VAR model in order to 1)identify the most important transmission channels in Russia and Belarus; 2)to determine the extent, to which the monetary policy instruments have been used as shock-absorbers for the Belarusian economy; 3)measure importance of the Russian shocks and the current Russian monetary policy for Belarus.

4.1 Approaches to the Empirical Analysis of the Monetary Policy

4.1.1 Analysis of the Monetary Policy Rules

The Taylor rule approach (Taylor 1993) provides a simple framework to estimate monetary policy rules. The basic specification represents a policy rule (nominal interest rate) as a function of output gap and deviation of inflation from the target. Although the Taylor rule may seem inferior to more sophisticated optimal policy rules, it is widely considered as an adequate and robust measure of the central banks' systematic behavior over the medium term. Woodford (2001) points that the rule incorporates features of the optimal policy by addressing fluctuations of both inflation and output and, thus, preventing self-enforcing destabilization of the economy.

CNB (2012) use a simple backward-looking Taylor rule while comparing cyclical positions of eight EU economies. For all countries, the equilibrium real interest rate and inflation targets are fixed at 2% level, while response coefficients to output and inflation gaps are both set equal to 0.5, following the original work of Taylor (1993). Then, implied interest rates are estimated for each country and their deviation from the implied euro area interest rate is interpreted as a measure of cyclical misalignment.

A number of studies questioned linearity of the central banks' response functions and suggested alternative specifications that could capture asymmetric monetary policy responses. The behavior of the monetary authorities may change depending on the direction and the magnitude of the fluctuations: upward deviations of inflation from the target may induce more aggressive policy than inflation undershooting; it may be also the case that the monetary policy is different in recessions compared to expansions. For example, Vasicek (2010) investigates whether monetary policy is asymmetric in the Czech Republic, Hungary, and Poland using two empirical approaches: 1) monetary policy rules are estimated assuming nonlinear forms of the underlying policy equations (the central bank reacting not only to inflation deviations, but also to its volatility) or economic structures (nonlinear Philips curve); 2) monetary policy rules are allowed to switch between two different regimes, which are identified based on the value of a threshold variable (inflation gap, output gap or financial distress serve as alternative transition variables). Jawadi *et al.* (2011) apply a similar approach to estimate response functions featured by the central banks of the

BRIC (Brazil, Russia, India, China) countries in 1990:1-2008:4. In order to account for gradual changes in the monetary policy, the rules are estimated using smooth transition regression (STR) specification. The authors find strong evidence for the nonlinearity. In particular, regarding Russia, the economic growth is reported to be the major driver of the monetary policy asymmetry (output growth rate below -1.4% being the threshold).

4.1.2 Evaluation of Monetary Policy Transmission

Monetary policy transmission determines how a monetary shock disseminates in the economy. Comprising a number of interconnected channels and various stages, the transmission mechanism is always complex and uncertain in reality. In theory and empirical works, though, it is common to distinguish between different transmission channels: interest rate, credit, exchange rate, and expectations. The interest rate channel acts through price rigidity. Monetary expansion leads to temporary decrease of the real interest rate, what positively affects investment and private consumption, thus, contributing to the overall increase of output. The credit channel operates via nonprice features, which determine credit availability. The traditional view on the credit channel is associated with asymmetric information and credit rationing. Monetary expansion reduces the default risk and the external finance premia, and eases the adverse selection criteria; the credit supply increases and stimulates borrowing and investment. In the emerging and transition economies, the effectiveness of the credit channel may be a consequence of the directed crediting. If the economic activity does not respond significantly to the changes in credit prices, monetary authorities may resort to directly controlling the credit supply by changing the banks' loanable resources. The exchange rate channel is important for open economies; yet, it may amplify as well as weaken the policy rate impulse. Monetary easing theoretically results in depreciation of the national currency; provided rigid domestic prices, depreciation benefits exporters and may contribute to the output growth. However, if price adjustment is fast, inflation rapidly wipes out advantages for exporters. Moreover, in case the economy is exposed to the exchange-rate risk via FX borrowing, depreciation of the national currency negatively affects the balance sheets of the firms and reduces wealth of the households. Expectations channel may ensure fast and powerful transmission of the monetary policy, under condition that the monetary authorities directly influence expectations by setting credible explicit targets. However, when the credibility is low, expectation channel, may, on the contrary undermine policy actions of the central banks. For instance, monetary expansion under high inflation expectations may result in the indexation or the currency substitution and, thus, have negligible or even negative effect on the real economy.

Starting from the seminal work of Sims (1980), VAR models have become common tools for analyzing transmission of monetary policy. Below we highlight several empirical works relevant to the OCA studies as well as those referring to the particularities of transmission mechanisms in Russia and Belarus.

Smets & Peersman (2001) investigate the importance of the common European monetary policy on the aggregate output and prices in the euro area countries. As a benchmark specification they use a monetary VAR model with endogenous (the euro area variables) and exogenous (the global economy) blocks. Having identified common monetary policy shocks, the authors then study their effects on output and prices of selected member-countries. A number of empirical works investigate monetary policy transmission in new or potential members of the euro area. Mackowiak (2005) uses a VAR specification with domestic and foreign blocks to decompose by origin the sources of the variation in output and price level in the Czech Republic, Hungary and Poland (CHP) and to measure relative importance of the euro area shocks for these countries. The German economy is used as a proxy for the euro area given strong ties between this country and the CHP economies and considerable weight of Germany in the EMU. The study concludes on significant effect of the euro area shocks on output and prices in CHP; moreover, it finds that euro area interest rate shocks have the same qualitative effects in CHP as in Germany, thus, pointing on the concurrence of the monetary policy transmission. Horvath & Rusnak (2009) apply a similar approach to analyze monetary transmission mechanisms in Slovakia. Their empirical results suggest that prior to the Euro adoption (January 2009) prices in Slovakia had been already largely driven by the ECB monetary policy shocks and that the Slovak Central Bank's monetary policy rule had followed closely the ECB's interest rates. In one of the recent papers, Darvas (2012) analyzes the monetary policy transmission in the CHP by the means of a time-varying VAR model. The author uses the methodology, which assumes that the reduced-form VAR parameters follow driftless random walks and applies the Kalman filter for maximum likelihood estimation and inference. His study indicates increasing impact of the monetary shocks over time in both the transition economies and the EMU and concludes on the growing strength of the domestic monetary policies. The major caveat is, though, the exclusion of the foreign sector from the VAR specification, which does not allow differentiating between the impact of domestic monetary shocks and those of the euro area.

Empirical studies comparing monetary transmission mechanisms in Russia and Belarus were conducted as part of the OCA research in 2000-2003. Tereshenko (2002a) estimates monetary VAR models separately for both countries and notes significant differences in the impacts of interest rates and money supply on output and prices. As we are unaware of later studies that directly aimed at comparing transmission mechanisms in Belarus and Russia, we further summarize some separate findings on the countries' monetary policy. Horvath & Maino (2006) estimate a VAR specification to analyze monetary transmission channels in Belarus in 1995-2005. They emphasize high pass-through of the exchange rate to both prices and output and note insignificance of monetary policy shocks for the real sector. The credit channel is reported operational to the extent of the authorities' intervention in the loan market. Abakumova & Komkov (2011) fit different VAR specifications to the Belarusian monthly time-series (2003-2010) to determine importance of the interest rate, the credit, and the exchange rate transmission channels for output variability. As in the previous studies, Abakumova & Komkov (2011) find no statistically significant impact of the refinancing and the interbank rates on the GDP, but observe some progress in the interest rate pass-through to the IPI.

As to the specific features of the monetary transmission in Russia, earlier studies (Vdovichenko & Voronina 2004; Vymyatnina 2005) report weak efficiency of both credit and interest rate transmission channels, explaining it by high level of dollarization. Recent studies (Balkovskaya & Filneva 2012; Leonteva 2012) observe some improvement in operationability of both transmission channels, which is still limited owing to high liquidity of the Russian banks, market concentration in the banking industry, and financial markets imperfections. Another factor is rigid loan pricing by the banks, which due to asymmetric information and substantial credit risk are unwilling to transmit lower policy rates to their clients (Sapunkova 2010). However, in 2010, the CBR claimed to gradually shift from the exchange-rate to the inflation targeting with the aim to achieve the regime change by 2015 (CBR 2012). Henceforth, in the nearest future, one may expect the increase of the interest rate efficiency for the monetary transmission in Russia.

4.2 Estimation of the Monetary Policy Rules

4.2.1 Models specification

Analysis of the monetary policy rules of the NBB and the CBR is conducted in two stages. First, we calculate implied policy interest rates using the Taylor rule with the same fixed parameters for both countries to compare cyclical positions of the Belarusian and Russian monetary authorities. Then, we estimate the monetary policy responses using the Taylor rule framework and assuming asymmetric reactions during recessions and expansions.

The implied interest rates are calculated following the classic Taylor rule (Taylor (1993)):

$$i_t = r_{eq} + \pi_t + 0.5(\pi_t - \pi_t^*) + 0.5(y_t - y_t^*) \tag{4.1}$$

Here i_t - nominal policy interest rate; r_{eq} - equilibrium interest rate; $(\pi_t - \pi_t^*)$ - deviation of inflation from the target, $(y_t - y_t^*)$ - output gap.

Further, for the policy rule estimation, we apply a linear Taylor rule that accounts for policy inertia and is defined as follows:

$$i_t = \rho * i_{t-1} + (1 - \rho)[\alpha + \beta(\pi_t - \pi_t^*) + \gamma(y_t - y_t^*)] + u_t \tag{4.2}$$

i_t - nominal policy interest rate; $(\pi_t - \pi_t^*)$ - deviation of inflation from the target, $(y_t - y_t^*)$ - output gap, u_t - i.i.d. disturbance term. Parameter ρ represents interest rate persistence, its high value may reflect unwillingness of the monetary authorities to frequently change the nominal interest rate; constant α can be interpreted as equilibrium real interest rate; β and γ characterize the strength of the monetary authorities' reaction to fluctuations of inflation and output. In case $\gamma = 0$ (is insignificant), β should be bigger than one as the real interest rate should increase in response to higher inflation in order to prevent further destabilization of the economy.

For the OCA analysis it is of particular interest to compare monetary policy rules during different stages of the business cycle in order to infer on the importance of monetary tools for the adjustment of the economy. (4.2) is modified to account for asymmetric responses during recessions (regime 1) and expansions (regime 2). For this purpose, we estimate a nonlinear Taylor rule that differentiates between the two regimes.

$$i_t = I * [\rho_1 * i_{t-1} + (1-\rho_1)[\alpha_1 + \beta_1(\pi_t - \pi_t^*) + \gamma_1(y_t - y_t^*)]] + \tag{4.3}$$

$$+(1-I) * [\rho_2 * i_{t-1} + (1-\rho_2)[\alpha_2 + \beta_2(\pi_t - \pi_t^*) + \gamma_2(y_t - y_t^*)]] + u_t;$$

$I = 1$ under regime 1 and is set to 0 for regime 2.

(4.3) is estimated using nonlinear least squares method. For a robustness check, (4.2) and (4.3) are extended to include other variables that might have affected behavior of the central banks: nominal exchange rate change, reserves growth rate, and money supply growth rate. These indicators had been used by both the NBB and the CBR as either direct or intermediate targets during some years between 2000 and 2012.

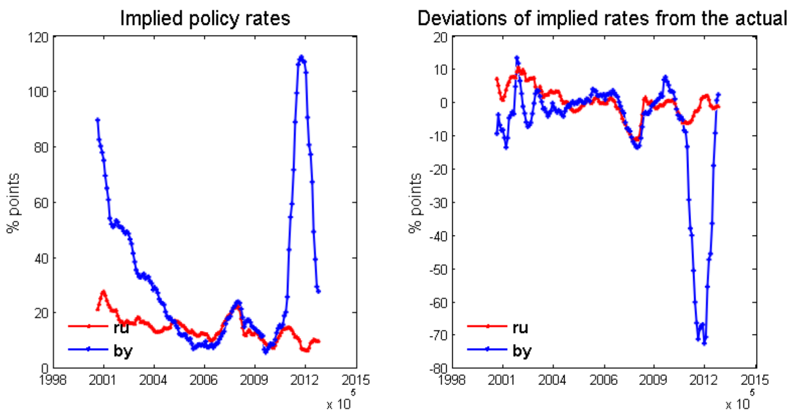
4.2.2 Data and Results

We use monthly data for both countries spanning from 2000:1 to 2012:12. As the policy interest rate, we chose the refinancing rate (monthly average, annualized), which represents the reference rate set by the NBB and the CBR for the operations involving liquidity provision to banks. To obtain annual inflation we take year-on-year logarithmic differences of the CPI. As a proxy for the inflation target, we use inflation trend obtained with the Hodrick-Prescott filter. Such approach is motivated by absence of explicit inflation targets for the early periods under study as both central banks officially targeted the nominal exchange rates. Moreover, such proxy tracks dynamics of the target. For Belarus, due to the presence of evident structural breaks, the target was calculated separately for three periods: 2000(1):2004(6) - period of macroeconomic stabilization with gradual decrease of the inflation target; 2004(7)-2011(1) - period of relative macroeconomic stability; 2011(2)-2012(4) - period following the currency crisis, the inflation target is fixed at 22% according to the explicit goal of the NBB. Seasonally adjusted monthly IPI is taken as a measure of output, and output gap is derived by the means of the Hodrick-Prescott filter.

For nonlinear specification we differentiate between two regimes: recessions and expansions. We define a recession as a period when the cyclical component of the output had negative growth rates and, consequently, an expansion as a period of increasing economic activity. For this procedure, we take the GDP as an output measure, since it characterizes more fully the state of the economy and is less noisy compared to the IPI. We proceed with the output gap (rather than with the growth rates) as both the Russian and Belarusian economies had had few absolute declines of the economic activity during the period under study. The output gap was obtained for the quarterly GDP with the Hodrick-Prescott filter and the regimes were identified following the Zellner's procedure (Zellner *et al.* 1990). The method consists in several steps. First, turning points of the business cycles (either peaks or troughs) are determined (a point is denoted as a trough if it is preceded and followed by two consecutive quarters with higher level of economic activity; peaks are defined accordingly). In addition, it is ensured that peaks and troughs alternate. Then, a period from a peak to a trough is marked as a recession and a period between a trough and a peak - as an expansion. After completing the Zellner's procedure, we interpolated the obtained series to fit monthly data.

The implied interest rates are calculated as in (4.1). To facilitate comparability, the CBR target is used for both countries; equilibrium natural interest rate is set at 3.5%. Figure 4.1 depicts the implied policy rates and presents deviations of the implied interest rates from the actual refinancing rates set by the NBB and the CBR in 2001-2012. Deviations are computed as simple differences between the refinancing rate and the implied rate. A negative deviation means that the actual rate was lower than the one prescribed by the Taylor rule.

Figure 4.1: Implied policy rates and their deviations from the actual refinancing rates of the NBB and the CBR in 2001-2012



Source: own computations.

Following the period of macroeconomic stabilization in Belarus and agreements on the Union State in the early 2000s, we observe high convergence of the economies' cyclical positions from 2005 up to 2010. The alignment of the implied rates indicates that the countries featured similar shocks to output and prices. It also points on the willingness of the NBB to follow the inflation targets perceived by the CBR. Importantly, the policy rates moved closely together also during the crisis of 2008-2009 and the early recovery period in 2010. Such relationship was disrupted in 2011 due to the currency crisis in Belarus that was accompanied by the burst of inflation. Misalignment in the behavior of the refinancing rates after 2010 could be caused by differences in the monetary policy transmission. While in Russia, post-crisis monetary easing facilitated output recovery; in Belarus, it contributed to higher inflation and devaluation expectations that forwarded the currency crisis.

We continue with estimating the policy rules for the NBB and the CBR. We start by fitting linear models to the countries' data. Table 4.1 presents the results of the OLS-estimation with robust standard errors.

Table 4.1: Estimation results: Linear monetary policy rules

Country	ρ (i_{t-1})	α (r_eq)	β ($\pi_t - \pi_t^*$)	γ ($y_t - y_t^*$)	ν *reserves*
Belarus					
coefficient	0.875***	0.153***	0.765**	-0.443	-0.083***
standard error	(0.041)	(0.048)	(0.326)	(0.367)	(0.031)
Model Checking:					
log-likelihood:	332.63				
AIC:	-655.25				
Ljung-Box Q(12)	131.24	[0.000]			
Russia					
coefficient	0.985***	0.053	4.219***	-0.093	–
standard error	(0.007)	(0.065)	(1.014)	(1.382)	–
Model Checking:					
log-likelihood:	592.75				
AIC:	-1177.51				
Ljung-Box Q(12)	32.90	[0.001]			

Source: own calculations.
*** - significance at 90% level, ** - significance at 95% level

Before proceeding with the analysis, several notes should be made. First, the coefficient (ρ) related to policy inertia may be overestimated as we use monthly series, where policy rates are autocorrelated by construction (pointed by Vasicek (2010)). That is also reflected in Portmanteau tests for the remaining autocorrelation in the models' residuals. Second, the constant's (α)

interpretation as the equilibrium real interest rate should be careful as we use Hodrick-Prescott trend to capture changing inflation targets; in this way, we assume time-variability of the real interest rate; in addition, mis-estimation of the inflation target could have taken place.

The parameters obtained with the linear specification indicate that both central banks changed interest rates in response to inflation fluctuations but not to deviations of output, with the CBR reacting more aggressively. Additionally, during the analyzed period the NBB responded significantly to the changes in the foreign reserves; policy rate slightly increased with the diminishing reserves, as the latter could have resulted in forced devaluation of the BYR and consequently created inflation pressures. Other variables: money supply and nominal exchange rate change - turned out to be correlated with inflation and insignificant for the policy rules of both central banks.

Parameter stability over time is checked with the CUSUM test that obtains a vector of one-step ahead forecast errors by running a series of regressions with increasing number of observations. For both countries, the parameter stability is not rejected. Non-linearity tests (RESET and squares) reject linear specification for the Belarusian data. The tests show that positive deviations of inflation from the target induce stricter responses of the NBB. Regarding the response function of the CBR, its linearity cannot be rejected at 95% confidence level.

We further estimate a nonlinear model that allows for asymmetric monetary policy reactions in recessions and expansions. The results are presented in the Table 4.2. The nonlinear specifications for both countries feature higher log-likelihood and smaller standard error of the residuals compared to the linear models. Autocorrelation in the residuals for the Belarusian data (as indicated by the Ljung-Box Test) remains high, but it is likely to be caused by the data characteristics rather than the estimation approach.

The reference rates of the NBB are more predictable by the proposed model during recessions: all regression coefficients are significant, while for the expansion regime only the autoregressive component (ρ) is important. Such result may be attributed to heterogeneous behavior of the NBB within the periods of growing economic activity. For instance, the central bank may have applied different response function, when output was increasing but remained below the desired level, compared to the one employed during near-the-peak times. At the time of recessions, the actions of the Belarusian monetary authorities were more uniform. In 2000-2012, downturns were usually characterized/caused by

Table 4.2: Estimation results: Asymmetric monetary policy rules

Country	ρ (i_{t-1})	α (r_{eq})	β ($\pi_t - \pi_t^*$)	γ ($y_t - y_t^*$)	ν *reserves*
Belarus					
Recession	78 obs				
coefficient	0.846***	0.151***	0.771***	-1.082*	-0.105***
standard error	(0.038)	(0.032)	(0.142)	(0.587)	(0.035)
Expansion	78 obs				
coefficient	0.935***	0.101	0.721	-0.825	-0.002
standard error	(0.031)	(0.082)	(1.253)	(1.142)	(0.07)
Model Checking:					
log-likelihood:	339.94				
AIC:	-659.89				
Ljung-Box Q(12)	117.69	[0.000]			
Russia					
Recession	52 obs				
coefficient	0.988***	0.035	4.588	-2.407*	-
standard error	(0.008)	(0.130)	(3.718)	(1.312)	-
Expansion	104 obs				
coefficient	0.985***	0.027	3.936**	2.849**	-
standard error	(0.007)	(0.073)	(1.743)	(1.308)	-
Model Checking:					
log-likelihood:	597.51				
AIC:	-1179.03				
Ljung-Box Q(12)	23.96	[0.020]			

Source: own calculations.

*** - significance at 90% level, ** - significance at 95% level inflation bursts and reserves depletion, which induced the NBB to increase the interest rate. Such particularity also explains significant negative coefficient in front of the output gap, as the actions of the NBB were focused on stabilization of prices.

For Russia, the monetary policy response function is more in line with the traditional view. Expansionary periods witnessed statistically significant positive reaction of the CBR to the fluctuations of both inflation and output in order to prevent further destabilization. Insignificant coefficients during recessions may be related to changeable nature of downturns that induced different responses of the CBR throughout the analyzed period or can reflect the preference of other monetary tools for adjustment needs.

As a summary of the current section, we would like to highlight the following observations. Conforming to our previous analysis in Chapter 3, cyclical positions of the Belarusian and Russian economies, as identified by the implied policy rates, were close in 2005-2010, thus suggesting strong alignment of real and nominal shocks. Discrepancy in 2011-2012 may have resulted from different transmission of the after-crisis monetary easing in Belarus and Russia. By estimating asymmetric Taylor rules we are able to obtain some additional evidence on the differences between the monetary policy functions of the NBB and CBR. In Belarus, the interest rate was primarily used to control inflation fluctuations and possible depletion of foreign reserves during downturns. Its reaction to the output dynamics turned out to be insignificant in both regimes. In Russia, during periods of growing economic activity, the CBR positively reacted to both inflation and output gaps and, closer than the NBB, followed the Taylor rule. These results favor the currency union with Russia. First, the interest rates in Belarus responded, above all, to temporary nominal shocks, which are likely to become less significant following monetary integration with Russia. This feature decreases the likelihood of high costs due to cyclical misalignment. Moreover, the Russian monetary policy during expansionary periods was more consistent aiming at macroeconomic stabilization. Consequently, the possible costs of the monetary union could be offset by the gains associated with importing lower inflation. Nonetheless, operationability of the CBR policy rule as a recovery tool during recessions was not confirmed by our estimations and could be a point of concern.

4.3 Monetary policy transmission

4.3.1 Model specification

As a benchmark model we choose a VAR specification with domestic and foreign blocks, following Smets & Peersman (2001) and Mackowiak (2005). This model has been widely applied in the studies of monetary policy transmission mechanisms in small open economies (Horvath & Rusnak 2009; Havránek *et al.* 2012, see), as it allows controlling for the effects of external shocks. Hence, apart from checking the hypothesis on monetary policy alignment, we should be also able to complement our previous findings on shocks synchronization by measuring portion of variation in the Belarusian variables that can be explained by the Russian data.

A structural model for two economies can be specified as follows (omitting constant and exogenous variables):

$$\sum_{j=0}^{p} A(j)y(t-j) = e(t) \tag{4.4}$$

Both $y(t)$ and $e(t)$ - are $[M \text{ x } 1]$ vectors with M being the number of variables; $y(t)$ represents a vector of endogenous variables, $A(j)$ is a $[M \text{ x } M]$ matrix of parameters with $A(0)$ being non-singular, $e(t)$ - data-generating structural disturbances (changes in technology, tastes, and policy). $e(t)$ are normally distributed with zero mean and constant variance normalized to one.

$$E(e(t)e(t)'|y(t-j), j > 0) = I_M.$$

Multiplying (4.4) by $A(0)^{-1}$ yields the reduced form of the VAR model:

$$y(t) = \sum_{j=1}^{p} B(j)y(t-j) + u(t) \tag{4.5}$$

$B(j) = A(0)^{-1}A(j)$; $u(t) = A(0)^{-1}e(t)$; $u(t)$ are normally distributed with zero mean and constant variance:

$$E(u(t)u(t)'|\ y(t-j), j > 0) = \Omega = A(0)^{-1}A(0)^{-1\prime} \tag{4.6}$$

The above relationships will be used to recover structural residuals and coefficients.

We can partition (4.5) into three sectors: the world (1), the Russian economy (2), and the Belarusian economy (3).

$$\begin{vmatrix} y_1(t) \\ y_2(t) \\ y_3(t) \end{vmatrix} = \sum_{j=1}^{p} \begin{vmatrix} B_{11}(j) & B_{12}(j) & B_{13}(j) \\ B_{21}(j) & B_{22}(j) & B_{23}(j) \\ B_{31}(j) & B_{32}(j) & B_{33}(j) \end{vmatrix} * \begin{vmatrix} y_1(t-j) \\ y_2(t-j) \\ y_3(t-j) \end{vmatrix} + \begin{vmatrix} u_1(t) \\ u_2(t) \\ u_3(t) \end{vmatrix}.$$

We assume that the Belarusian shocks affect neither the Russian, nor the world economies, while the inverse holds. As to the effect of the Russian shocks on the world economy, no prior restrictions are imposed as it is likely that fluctuations in Russia might alter behavior of some world variables. Thus, we impose block-exogeneity restrictions on matrices $B(j)$ only relative to Belarus by setting $B_{13}(j) = 0$ and $B_{23}(j) = 0, j = \bar{0,} p$.

We analyze dynamic interaction of the following variables: output, price level, short-term interest rate, monetary aggregate, and nominal exchange rate for the Russian and Belarusian economies and crude oil prices. Further in the text, the variables entering each sector are denoted as follows:

$$y_1(t) = oil(t);$$

$$y_2(t) = x_{ru}(t), p_{ru}(t), i_{ru}(t), m_{ru}(t), er_{ru}(t);$$

$$y_3(t) = x_{by}(t), p_{by}(t), i_{by}(t), m_{by}(t), er_{by}(t);$$

where $x(t)$ denotes output, $p(t)$ - price level, $i(t)$ - short-term interest rate, $m(t)$ - monetary aggregate, $er(t)$ - exchange rate, $oil(t)$ - crude oil price.

In order to interpret the model, one needs to recover structural coefficients and shocks. Since estimation of a reduced form yields fewer coefficients, we need to impose a number of restrictions on structural parameters of the model. For a system to be just-identified, $M*(M-1)/2$ restrictions are to be imposed (M being the number of variables). For identification we apply Cholesky recursive scheme. Technically, Cholesky procedure decomposes a matrix X on a lower triangular matrix and its conjugate transpose, such that $X = L * L'$. (4.6) describes the same relationship between the variance-covariance matrix (Ω) of the observed residuals and $A(0)^{-1}$. Thus, in order to derive $A(0)^{-1}$, one needs just to perform a Cholesky decomposition of Ω. Upper-triangular form of the inverse $A(0)$ matrix may have a plausible economic interpretation. From (4.5), $u_t = A(0)^{-1}e_t$, i.e. observed shocks are combinations of structural disturbances. Restrictions are imposed on the matrix $A(0)^{-1}$, in such way that the structural shocks to some variables (lower-order) are not allowed to affect other (upper-order) variables contemporaneously. Restricted $A(0)^{-1}$ for the baseline model is presented below from upper- to lower-ordered variables:

$$oil(t), x_{ru}(t), p_{ru}(t), i_{ru}(t), er_{ru}(t), m_{ru}(t),$$

$$x_{by}(t), p_{by}(t), i_{by}(t), er_{by}(t), m_{by}(t).$$

$$\begin{vmatrix} \mu_1(t) \\ \mu_2(t) \\ ... \\ \mu_{10}(t) \\ \mu_{11}(t) \end{vmatrix} = \begin{vmatrix} 1 & 0 & 0 & ... & 0 \\ a_{2,1} & 0 & 0 & ... & 0 \\ ... & ... & ... & ... & ... \\ a_{10,1} & a_{10,2} & a_{10,3} & ... & 0 \\ a_{11,1} & a_{11,2} & a_{11,3} & ... & 1 \end{vmatrix} * \begin{vmatrix} \epsilon_1(t) \\ \epsilon_2(t) \\ ... \\ \epsilon_{10}(t) \\ \epsilon_{11}(t) \end{vmatrix}.$$

Here, $\mu_M(t) \subset u(t)$ - observed shocks to individual variables (residuals of the estimated VAR model in the reduced form) and $\epsilon_M(t) \subset e(t)$ - structural shocks. According to such ordering, the lowest-order variable (the Belarusian monetary aggregate) reacts contemporaneously to structural shocks in all variables of higher order, while the highest-order variable (crude oil price) features totally independent shock and may be influenced only by lags of some Russian indicators. The exchange rate is ordered before the monetary aggregate, since both the CBR and the NBB officially targeted the former during most part of the analyzed period and attempted to limit its fluctuations. Bearing in mind that estimation results may be sensitive to changing the identification scheme, we impose alternative orderings (with different relative positions of exchange rate, interest rate, and monetary aggregate) for a robustness check.

Stability of a VAR model is viewed as an important issue, since non-stable specifications may result in spurious correlations and incorrect inference. Consider a reduced-form VAR as in (4.5). Its deterministic part can be rewritten using a lag operator as

$$B(L)y(t) = (I_M - B_1L - B_2L^2 - ... - B_pL^p)y(t) \tag{4.7}$$

By calculating the roots of (4.7), one can examine the stability of a VAR. The inverse polynomial of (4.7) is defined as

$$P(z) = (I_M - B_1z - B_2z^2 - ... - B_pz^p)$$

The characteristic roots of $|P(z)| = 0$ provide information about stability of the model. The necessary and sufficient condition for stability is that all roots of the inverse polynomial lie outside the unit circle. That implies the system, on the whole, is stationary and the series do not diverge to infinity due to shocks.

In the empirical literature there has been no general consensus on whether it is necessary to difference non-stationary time-series (such as output, price level, etc.) before using them in a VAR model. Sims (1980) advised against differencing as it induced information loss, in particularly, regarding comovement of variables and possible cointegrating relationships. It is also recommended against detrending the series, as a VAR specification allows approximating for a trending variable (Enders 2009). A VECM can serve as a solution for non-stationary data. Yet, stationarizing a model by the means of cointegration operators is often unnecessary when it appears that the series are comoving. Morever, in small samples it might be statistically difficult to decide on the presence of significant cointegrating relationships, while setting the cointegrating restriction inappropriately could lead to incorrect conclusions. Following the presented argumentation, it is common to estimate VARs in levels and allow for only implicit cointegrating relationships in the data.

4.3.2 Data

We input monthly time-series spanning from 2000:M1 and 2012:M12. Table 4.3 provides a brief description of the variables used in the baseline model and their alternatives for a robustness check.

Table 4.3: Dataset description for the VAR model

Indicator	**Baseline**	**Alternative**
Output	IPI	GDP
Prices	CPI	PPI
Interest rate	refinancing rate	interbank 1-day MM rate
Monetary aggregate	M2	credit to private sector
Exchange rate	nominal exchange rate index	
World economy	crude oil price index	

Source: own compilation.

In the baseline model, the IPI proxies the output; the choice of this indicator was motivated by its availability on monthly basis. Besides, the application of the GDP as an alternative measure bears a number of caveats: apart from being subject to the interpolation bias, models employing this indicator ex-post could lead to incorrect inference, as the most recent GDP measures are usually unavailable at the point of the monetary decision-making. Notwithstanding, the IPI also features important drawbacks: first, it does not fully characterize the economy; second, the data on the industrial production is usually noisy. To control for the first problem, a VAR specification with the GDP is estimated for a robustness check (quarterly GDP series were converted to monthly using cubic spline interpolation method). To account for high-frequency fluctuations in the IPI series, we employed available seasonally-adjusted time-series and performed additional smoothening via the Butterworth low-pass filter. The filter approximates an ideal square-wave filter, which allows frequencies over a certain range to pass at full strength while stopping all others. We set parameter order to $n = 8$ and cutoff value to 67 in order to exclude short-term fluctuations.

Price level is characterized by the CPI for both countries. To complement the analysis we also estimate a VAR with the PPI for Russia as a price variable. Unlike the Belarusian PPI inflation, which moved closely with the CPI, changes of the PPI and the CPI in Russia were not strongly symmetric. Moreover, the PPI is mostly composed of tradable-goods prices and, thus, it is a more informative indicator, when we aim on measuring importance of the Russian shocks for the Belarusian economy.

The refinancing rates set by the CBR and the NBB enter the model as monetary policy rule variables. Besides, we estimate a VAR with the Russian interbank money-market 1-day interest rate to additionally infer on the speed of the Russian monetary policy transmission in Belarus.

We use the monetary aggregate M2 (monetary base plus on-demand, saving, and term deposits in the national currency) for both countries as measure of money supply in the baseline specification. As an alternative proxy we take domestic credit (to nonfinancial private organizations and households) that allows estimating the role of credit availability in the Belarusian and the Russian economies, while eliminating the effect of the crediting to the state sector. In 2010-2012, volumes of credit to nonfinancial state enterprises in Belarus constituted more than 40% of the total domestic credit to nonfinancial entities and households (in 2005-2009, its share made up slightly more than 20%). In Russia, the corresponding indicator has steadily decreased and in 2010-2012 was equal, on average, to 1.4%.

Exchange rate dynamics is described by the index of nominal exchange rate (foreign currency per 1 unit of the national currency). For Belarus, we employ the effective exchange rate, while for Russia - nominal USD/RUR rate. As a variable characterizing the world, we chose crude oil price index (Brendt prices), since oil and oil products constitute about 50% of the Russian exports and account for around 40% of both the Belarusian imports and exports.

The sources of the country data are the online statistics databases of the NBB and the CBR; the IPI time-series are available in the online database of the UNECE (the United National Economic Commission for Europe).

In total, we perform estimations for four slightly different datasets:

- baseline model with the variables as in the first column in the Table 4.3;
- a specification with the domestic credit to the private firms and the households to have an additional insight on the credit channel operationability;
- a specification with the PPI as the price level proxy and the interbank interest rate as the policy rule for Russia to better capture penetration of the Russian shocks in the Belarusian economy;
- a specification with the GDP as a broader output measure.

We estimate the first three specifications in levels to exploit maximum information available, while, in the fourth option, we detrend GDP with the Hodrick-Prescott filter and take year-on-year differences of other time-series to control for possible spurious regressions.

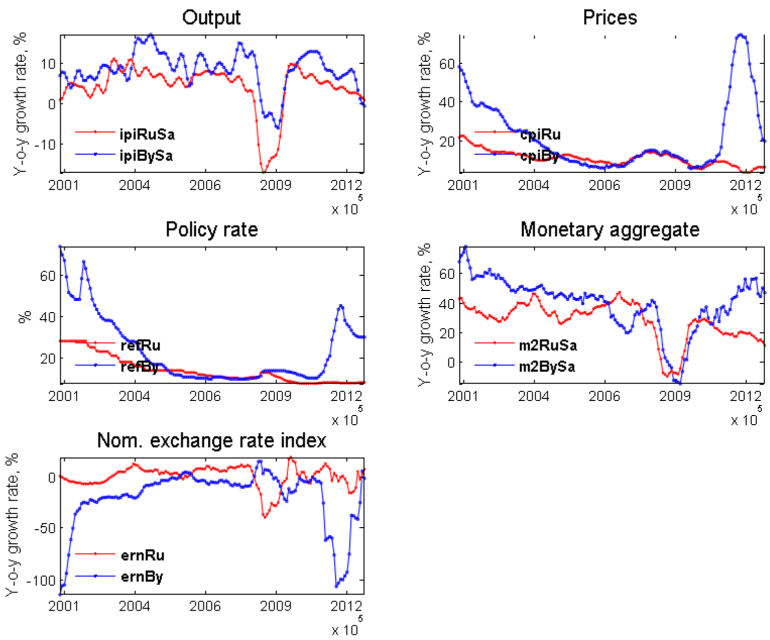
4.3.3 Results and Discussion

The section compares monetary policy transmission in Belarus and Russia; evaluates relative importance of the Belarusian domestic monetary policy tools for adjustment to shocks and estimates the portion of the economic fluctuations in Belarus that are due to foreign disturbances.

The variables entering the baseline specification are sited in Table 4.3. All the series (except for the interest rates) are in logarithms. Prior to the VAR-estimation, we conducted Johansen cointegration test (Table A.1 in the Appendix A), both Trace and Lmax tests indicated the presence of cointegrating relationships; thus, we are likely to get a stable system when estimating the

VAR in levels. Figure 4.2 depicts plots of the series entering the baseline specification (except for the interest rates, the series were seasonally differenced to ensure better comparability between the countries).

Figure 4.2: The time-series entering the baseline VAR model, %

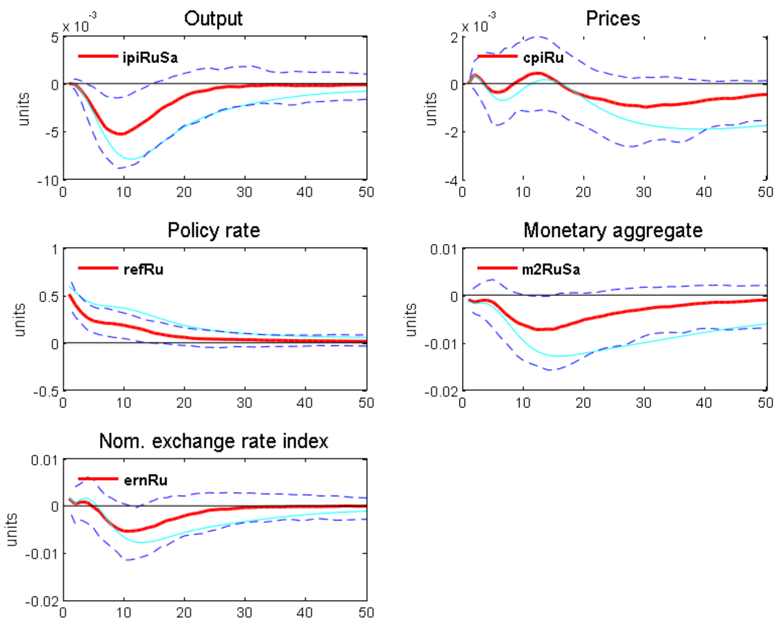


Source: NBB Statistics Database, CBR Statistics Database, National Statistical Committee of the Republic of Belarus, Federal State Statistics Service of the Russian Federation.

We impose a block-exogeneity restriction on the Belarusian variables entering the Russian and the world blocks. Beforehand, we conducted a Granger causality test, which confirmed insignificance of the Belarusian variables (except for the IPI) for the foreign indicators (Table A.1 in the Appendix A). The test was performed on the differenced series, because, for the integrated data, the usual asymptotic distribution of the test statistic may not be valid under the null hypothesis. We estimate VAR with a constant and a trend and set the lag length to 2 according to the Schwarz information criterion. Lag length of 2 seemed also plausible based on the Ljung-Box Test of residuals. The test indicated autocorrelation only for the IPI and the Russian CPI residuals (at 0.05% confidence level); the systematic relationship in the error term is probably the result of the imperfect adjustment procedures. We decided not to correct for that problem by overparameterizing equations for other variables, as estimated coefficients remain unbiased under autocorrelation, though no longer efficient. The test of the VAR roots reported that the eigenvalues of the inverse polynomial are outside the unit circle. Generated impulse responses converge to zero. Thus, we conclude on the stability of the system and possibility for further inference.

The identification scheme was applied as described in the previous section. Figure 4.3-Figure 4.4 below depict impulse responses to the structural interest rate shocks in Belarus and Russia and allow comparing the monetary policy transmission channels in the countries. These and further figures show the generated impulse response (light blue line), the median of 100 impulse response replications (bold red line), and 90% confidence bands (dashed lines) obtained with the bootstrapping procedure. In the text, we present impulse responses for the baseline model. The results from the alternative estimations together with the code can be found in the electronic supplement (*ch4/mp_transmission*).

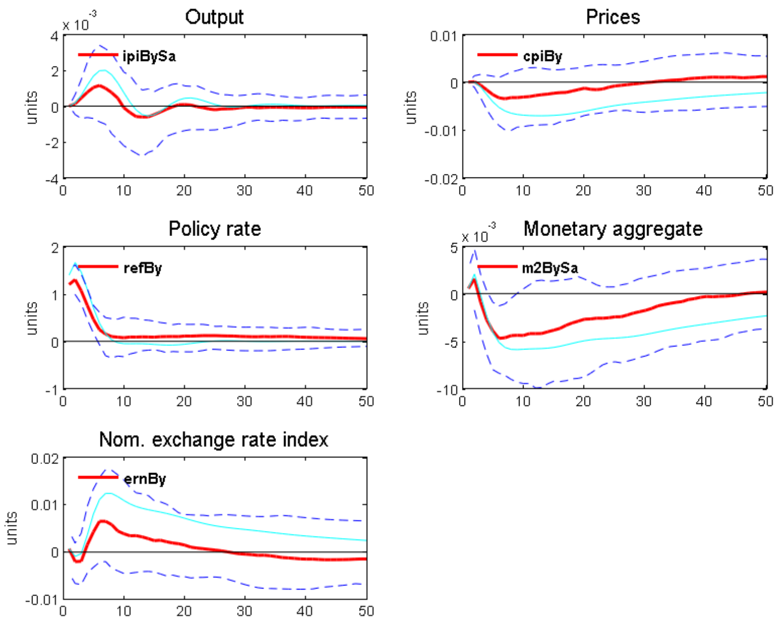
Figure 4.3: Impulse responses to a refinancing rate shock in Russia (1 st.dev shock), units



Source: own computations.

The policy interest rate increase has statistically significant negative impact on the Russian output and money supply with the latter enforcing the transmission. The effect on the output peaks in 10 months after the refinancing rate shock and dies out in 1.5 years. Reaction of the nominal exchange rate is on the edge of significance. Rather than appreciating, it reaches a negative peak 10 months after the interest rate rise, since its dynamics is related with the expectations about the output activity: projected lower production results in lower demand for the RUR and its consequent depreciation. The response of the CPI is not significant, what may have been caused by the misspecification of the price level equation (above, we reported remaining autocorrelation in this series). With the alternative variables, somewhat stronger responses of the CPI to the policy rate shock can be obtained. When credit is considered instead of the money aggregate M2, the CPI still fluctuates in response, but features a trough (on the border of the significance band) 7 months after a positive interest rate shock (see electronic supplement *ch4/mp_transmission/output/priv_credit.html*). The reaction of the PPI to the interbank interest rate change is more clear with a bell-shaped impulse response reaching a trough in 10 months and returning to zero in 2 years (Figure A.1).

Figure 4.4: Impulse responses to a refinancing rate shock in Belarus (1 st.dev shock), units

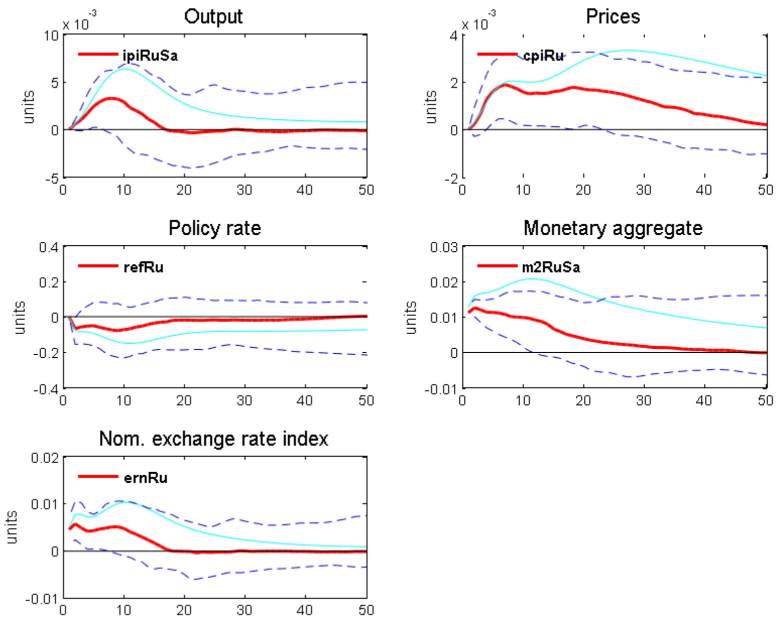


Source: own computations.

In Belarus, the refinancing rate shock is less persistent than in Russia and, according to the baseline model, affects significantly only M2. The money supply initially increases as the amount of deposits in the national currency may go up following higher interest rates; but after 5 months reaches a trough (due to decrease in banks' liquidity and credit contraction). The effect on the output is insignificant, pointing on lower than in Russia sensitivity to the credit costs and may be related to bigger volumes of directed crediting. Responses of the CPI and the nominal exchange rate are clear, but significant only at 85% confidence level. Difference in the RUR and BYR exchange rate reactions to the interest rate shock are noticeable: increase of the NBB refinancing rate, through the expectations channel, leads to the currency appreciation (revaluation) that peaks in 9 months and augments the effect of the interest rate shock.

Following previous studies on the monetary policy transmission mechanism in Belarus and Russia, we also analyze the pass-through of money supply shock to output and prices (Figure 4.5-Figure 4.7).

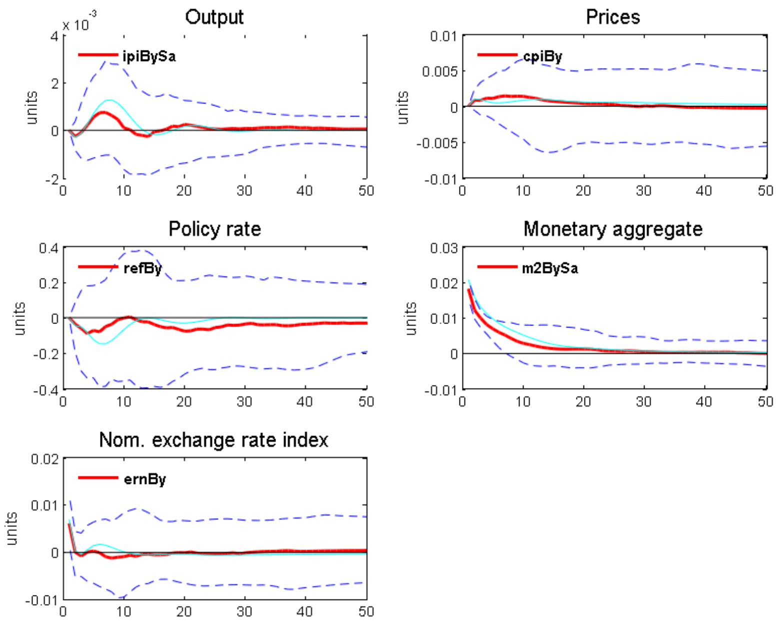
Figure 4.5: Impulse responses to a money supply shock in Russia (1 st.dev shock), units



Source: own computations.

A shock to the money supply in Russia results in statistically significant feedback of real and nominal variables with a comparable length of transmission to the interest rate shocks: the peaks of output and price level deviations happen in 7-8 months after the money supply impulse. Nominal exchange rate appreciates in response to the positive outlook for output dynamics. When credit to private sector is considered instead of M2, the generated impulse responses do not vary from those obtained with the baseline version. In the specification with the PPI and the interbank interest rate, the response of the latter is fast (with a peak in 2 months) and strongly significant. It can indicate that change in the money supply has been employed by the CBR as an alternative monetary policy instrument and has been transmitted rapidly in the economy through the money market.

Figure 4.6: Impulse responses to a money supply shock in Belarus (1 st.dev shock), units

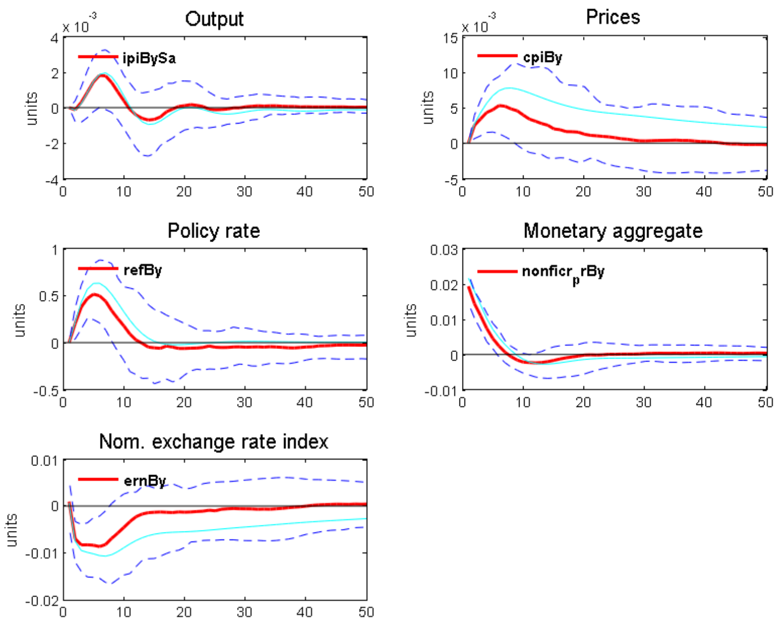


Source: own computations.

In Belarus, a shock to the money supply generates no or weakly significant responses of nominal and real variables. A stronger feedback is obtained when credit to private sector (firms and households) is considered instead of the monetary aggregate M2. Indirectly, it points on low efficiency of credits to the state enterprises. The increase in the credit availability for private sector, amplified by the exchange rate depreciation (devaluation), stimulates output and contributes to increase in price level, which in its turn induces the policy rate to increase. Thus, we can conclude that the NBB may influence output dynamics by changing credit availability and, in this way, affecting the internal demand. Notwithstanding, this measure can have only a short-term positive effect.

Table 4.4 and Table 4.5 present the variance decomposition of output and prices. In the short term (6 months) neither of the monetary policy tools is important for the output variability in both countries. In the medium term (24 months), the reference rate and the money supply contribute the most to

Figure 4.7: Impulse responses to a credit shock in Belarus (1 st.dev shock), units



Source: own computations.

the forecast error of the Russian production (51%, with the refinancing rate being the most important). Low contribution of the nominal exchange rate shocks indicates that the RUR exchange rate is mainly a shock absorber for the Russian economy, rather than shock generator. In Belarus, own monetary policy instruments remain insignificant for production, which is in large driven by the change in the Russian real and nominal variables.

Regarding price level dynamics in both countries, CPI variance is mostly determined by its own shocks, hence, suggesting preponderance of expectations. Changes in the Russian money supply generate about 25% of CPI forecast error in both Russia and Belarus in the medium term. Meanwhile, the share of domestic monetary policy instruments in the Belarusian prices variability constitutes 4%. Small weight of the own monetary tools in the variance of the Belarusian output and prices can be justified by importance of the Russian shocks for the Belarusian economy (it is explored in more detail below). Therefore, when orthogonal shocks are considered, the "value added" of the original Belarusian disturbances becomes small.

By considering effects of domestic shocks to output and prices (Figure 4.8-Figure 4.11) we may conclude on the significance of various monetary policy

Table 4.4: Variance decomposition of output

ipiRuSa						
Period	**oil**	**ipiRuSa**	**cpiRu**	**refRu**	**M2Ru**	**ernRu**
6	[0.2220]	[0.6862]	[0.0065]	[0.0387]	[0.0442]	[0]
24	[0.0977]	[0.3957]	[0.1038]	[0.2470]	[0.1451]	[0.0107]
ipiBySa						
Period	**oil**	**ipiRuSa**	**cpiRu**	**refRu**	**M2Ru**	**ernRu**
6	[0.2037]	[0.2145]	[0.0261]	[0.0186]	[0.0183]	[0.0027]
24	[0.1299]	[0.2304]	[0.0907]	[0.1611]	[0.1579]	[0.0174]
Period		**ipiBySa**	**cpiBy**	**refBy**	**M2By**	**ernBy**
6		[0.4912]	[0]	[0.0159]	[0.0033]	[0.0049]
24		[0.1841]	[0.0104]	[0.0113]	[0.0044]	[0.0023]

Source: own computations.

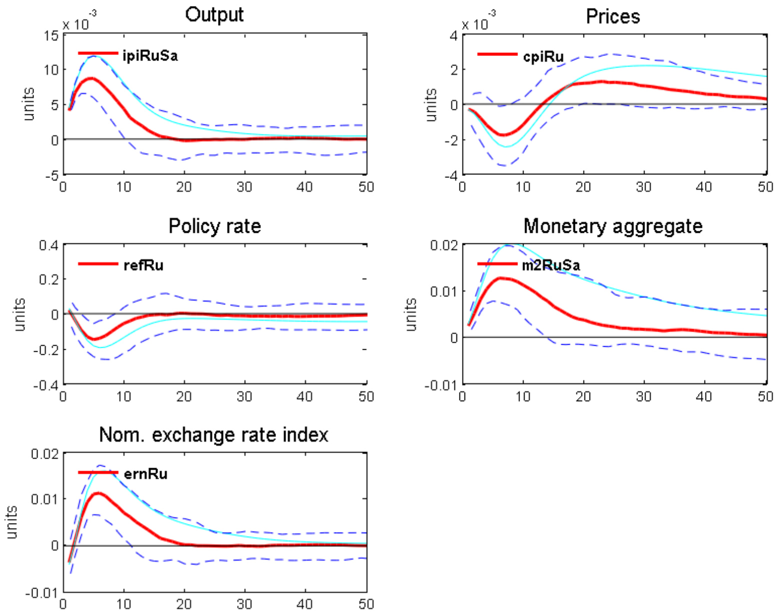
Table 4.5: Variance decomposition of prices

cpiRu						
Period	**oil**	**ipiRuSa**	**cpiRu**	**refRu**	**M2Ru**	**ernRu**
6	[0.0211]	[0.0620]	[0.8669]	[0.0045]	[0.0360]	[0.0095]
24	[0.0405]	[0.1242]	[0.5456]	[0.0148]	[0.2542]	[0.0203]
cpiBy						
Period	**oil**	**ipiRuSa**	**cpiRu**	**refRu**	**M2Ru**	**ernRu**
6	[0.0129]	[0.0037]	[0.0032]	[0.0244]	[0.0273]	[0.0663]
24	[0.0101]	[0.0121]	[0.0160]	[0.0660]	[0.2663]	[0.1700]
Period		**ipiBySa**	**cpiBy**	**refBy**	**M2By**	**ernBy**
6		[0.0044]	[0.8097]	[0.0134]	[0]	[0.0339]
24		[0.0022]	[0.4078]	[0.0397]	[0]	[0.0094]

Source: own computations.

tools for the stabilization of the economies.

Figure 4.8: Impulse responses to an output shock in Russia (1 st.dev shock), units

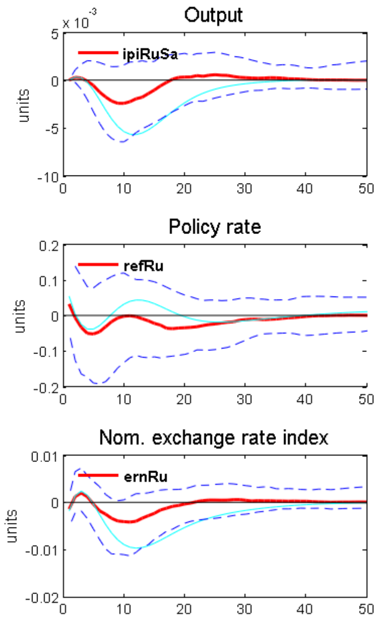


Source: own computations.

In Russia, a shock to output peaks in 3 months and dies out in 1.5 years. The exchange rate is the fastest to react. In response to a positive output shock, the exchange rate appreciates, what may be interpreted as a consequence of higher demand for the RUR due to intensifying export activities (in particular, export of oil products). Then, an output shock is transmitted to the money supply and the interest rate (with improving liquidity of the Russian banks). An output shock positively affects the producers' price level, while the consumer prices (Figure 4.9) respond at the edge of significance: firstly, with a drop (that could be due to the RUR appreciation) and, after 20 months, with a peak caused by money supply growth and interest rate decrease.

Consumer price shocks in Russia die out after 20 months (Figure 4.9). According to our estimations, they result only in marginally significant feedback of the exchange rate that reaches a trough 10 months after a positive price fluctuation. Behavior of other variables (including the reference rate of the CBR) is uncertain. Somewhat better results (weakly significant increase of the interest rate in responce to a positive price shock) are obtained for a model with the PPI and the interbank interest rate (Figure A.1). The generated impulse

Figure 4.9: Impulse responses to a price shock in Russia (1 st.dev shock), units



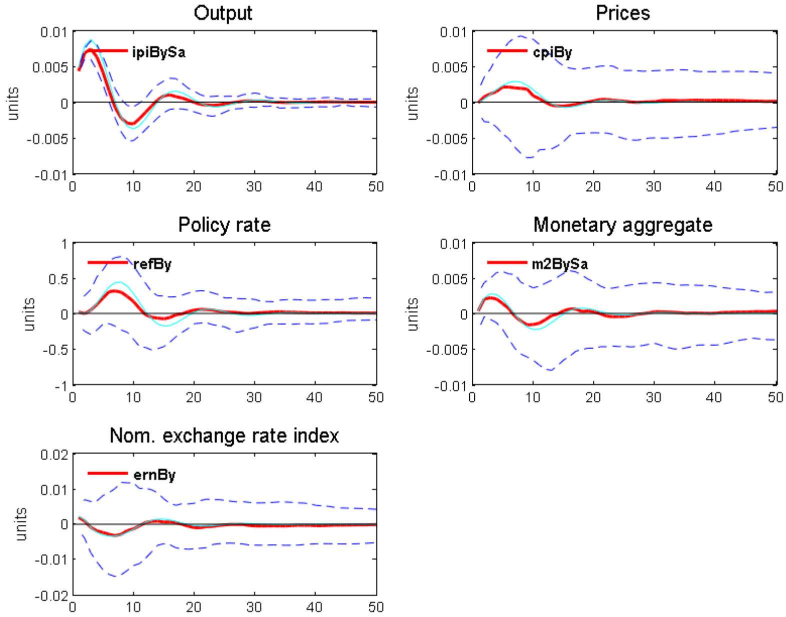
Source: own computations.

responses to output and price shocks in Russia, to some extent, challenge our conclusions from the previous section: we do not find evidence of the counter-cyclical behavior of the Russian monetary authorities (aimed on stabilization of output and prices). Nonetheless, the structural shocks identified with a VAR in levels may not correspond to the inflation and output gaps that presumably enter the central bank's response function. Moreover, the results are not robust to different inflation measures and may be sensitive to the number of included lags and possible asymmetries.

In Belarus (Figure 4.10), output shocks are less persistent and disappear in 7 months. Pure Belarusian output fluctuations do not generate significant impulse responses; the weight of output shocks in the variance decomposition of other variables does not surpass 1% in the medium term.

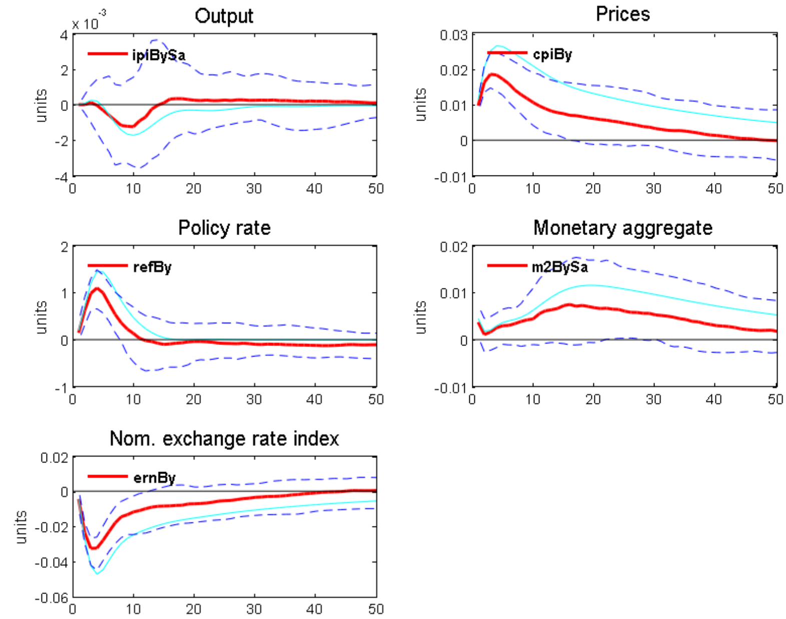
A price shock (Figure 4.11), in contrast to Russia, is more persistent than the output disturbance (reflecting difficulties the NBB faces with inflation); it takes around 3 years for the price level to return to the equilibrium. The shock induces reaction of only nominal variables. The BYR rapidly loses value following a positive price shock. Dynamics of the interest rate points on the attempt of the NBB to stabilize the prices.

Figure 4.10: Impulse responses to an output shock in Belarus (1 st.dev shock), units



Source: own computations.

Figure 4.11: Impulse responses to a price shock in Belarus (1 st.dev shock), units



Source: own computations.

Further, we analyze relative importance of foreign shocks. Positive fluctuations of oil prices result in statistically significant feedback of both real and nominal indicators for Russia, illustrating dependence of the Russian economy on the oil industry. Variance decomposition of the forecast errors shows that changes in the world oil prices in the medium term account for 10% of the output variability and 20% of the producers' prices deviations (however, they explain only about 4% of the consumer prices variance).

For the Belarusian economy, changes in the oil prices have strong impact only on the output indicator (the effect is mainly transmitted through the changes in the Russian output). As to the variance decomposition, oil prices fluctuations are responsible for about 13% of the Belarusian output variability, which is comparable to the feedback of the Russian indicator.

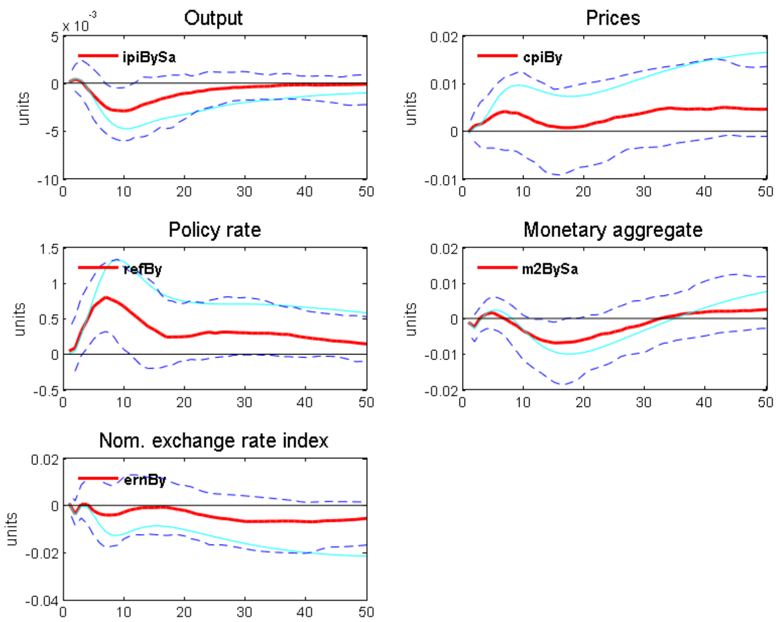
Importance of the Russian shocks for the Belarusian economy is significant; fluctuations of the Russian real and nominal variables explain up to 75% of the variability of the Belarusian indicators. The Russian output shocks turn out to be the major factor of the variability of the Belarusian economic activity by explaining around 20% of its forecast error in both short and medium terms. The Belarusian consumer price level variance is strongly affected by the change of the Russian money supply and the nominal exchange rate of the RUR, which contribute accordingly 26% and 17% to the CPI forecast error in the medium run. In total, imported inflation from Russia can be roughly estimated at 53% in a 2-year horizon. Since we did not account for any other world variable, except for the oil prices, weight of the Russian economy is likely to be overestimated; from another side, it indicates that the external shocks affecting the countries are often symmetric.

The CBR reference rate is responsible for 9% of the NBB reference rate variability in the short run with its share increasing to 29% in 24 months. A shock to the CBR policy rate is also found to cause significant deviations of the

NBB policy rate (Figure 4.12). Unlike domestic monetary policy shocks, a fluctuation of the CBR reference rate results in statistically significant reaction of the Belarusian output; the impulse is mainly transmitted via the change of the Russian output.

Impulse responses of the Belarusian variables to the RUR nominal exchange rate change show low degree of the countries' exchange rates synchronization. For instance, increase of the RUR value relative to the USD leads to decrease of the effective nominal exchange rate index of the BYR, higher price level (as

Figure 4.12: Impulse responses to the CBR reference rate shock in Belarus (1 st.dev shock), units



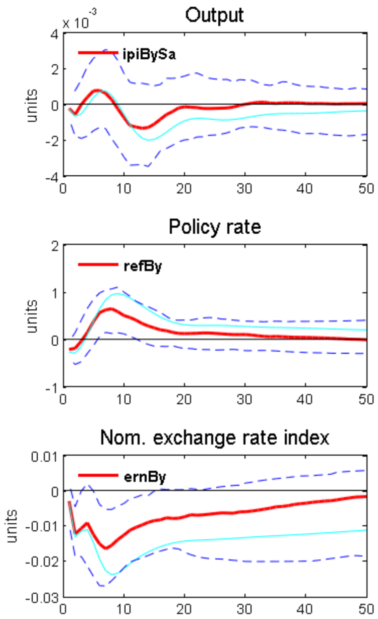
Source: own computations.

the speed of price adjustment for imported goods is high), and consequently higher reference rate of the NBB.

Inspection of the exchange rate variance decomposition shows further differences. Nominal exchange rate of the RUR is mostly determined by movements of output and world oil prices that account accordingly for 30% and 16% of the RUR nominal exchange rate forecast error variance in the medium term. The BYR nominal effective exchange rate variance features the smallest (among other Belarusian variables), but still considerable share of the Russian shocks: around 20% in the short run and 50% in the medium term. Its major determinant, though, is the Belarusian price level (65% in the short term). After 24 months, the weight of domestic prices remains at almost 40%. While in Russia, the exchange rate serves as absorber of the real domestic and external demand shocks, in Belarus, its variability is largely determined by unanchored inflation expectations and historic mistrust to the BYR. Based on our analysis, we cannot conclude that the Belarusian nominal exchange rate plays a significant role as an adjustment tool to real fluctuations.

For s robustness check, we fitted a VAR model to the stationarized series: the GDP gaps, seasonal differences for other variables. With the alternative

Figure 4.13: Impulse responses to the RUR nominal exchange rate shock in Belarus (1 st.dev shock), units



Source: own computations.

data we obtained similar results, but the model fit is inferior to the baseline choice in terms of lower log-likelihood and information criteria and presence of higher autocorrelation in the residuals. Similar results were also obtained when alternative identifying restrictions were imposed. The matlab code and additional output can be found in the Appendix.

Possible bias of the estimation results could be related to the time-variability of the model parameters that is usually the case for transition economies. However, in this work, we restrain from dividing the data and conducting estimation for subsamples separated by possible structural break(s): the characteristics of the earlier and the later parts of the whole sample are different (the first half of 2000s was characterized by gradual macroeconomic stabilization, while major crises happened after 2008). The substantial change in the Belarusian monetary policy took place after the currency crisis in 2011 (two years of observations would not be enough to draw any valid conclusions on the changes in the monetary policy transmission). In Russia, the transformation of the monetary policy (from the exchange rate to the inflation targeting) is expected to be completed only by 2015. A potential improvement could be obtained by employing a TVAR (time-varying VAR) specification that would allow for asymmetries under different regimes (i.e. based on a threshold value of a transition variables). In that case, it would be problematic to estimate a two-sector VAR model to account for the effect of the Russian and the world shocks on the Belarusian economy. Yet, the appropriate fit of a time-varying VAR model to the Belarusian and Russian data could complement the findings of the present work.

The conducted analysis has revealed a number of differences in the monetary policy transmission between the countries. In Russia, the monetary policy shocks (interest rate and money supply) affect both nominal and real variables. As to the Belarusian data, we can conclude on the importance of the NBB policy tools for the nominal variables; but their effect on the output is weak (inconsistent). The Belarusian output responds marginally significantly only to the change in the volumes of domestic credit to private sector. In contrast to the Russian economy, the credit transmission channel in Belarus is more operational relative to the interest rate channel.

A monetary policy shock in Russia is amplified through the change in the money supply, while the nominal exchange rate channel contributes to the shock only initially; its further behavior is mainly determined by output dynamics. In Belarus, on the contrary, the exchange rate plays a significant role in the transmission of the monetary policy shocks by reenforcing the effect of the interest rate change, as perceptions of the BYR value are closely linked to the inflation expectations and vice versa. Fundamental differences in the nominal exchange rate determination should be noted. In Russia, the value of the RUR is mainly determined by the output dynamics and the world oil prices. In Belarus, the dynamics of the nominal exchange rate is strongly affected by expectations, while contribution of real variables and oil prices is negligible.

Some of the aforementioned differences could be attributed to asymmetric nominal shocks and higher inflation expectations that influence monetary policy transmission in Belarus. This type of misalignment is not a serious counterargument against the monetary union, as the nominal asymmetries are expected to be reduced once the countries are subject to the single monetary policy. Besides, the importance of the Russian shocks for the Belarusian economy is significant: the movements of the Russian variables explain from 50% (the BYR nominal exchange rate) to 75% (the output) of the variance of the Belarusian indicators in the medium term. The policy rate of CBR generates significant responses of the Belarusian production (following the change of the economic activity in Russia). At the same time, different interest rate pass-throughs indicate that the Belarusian financial market is less sensitive to the cost of credit. That may be the consequence of high weight of the state sector in the Belarusian economy and its reliance on the directed crediting. Privatization reforms may be required prior to the monetary integration. In addition, opposite reactions of the nominal exchange rates to shocks reflect differences in the industry structures. For instance, oil-driven appreciation of the RUR (once the single currency) may create unfavorable conditions for the Belarusian exporters and, in the absence of alternative stabilization channels, can lead to public indebtedness (and tensions within the union), thus increasing the costs of the monetary integration for Belarus.

Chapter 5

Estimating Welfare Losses of Alternative Monetary Policies

This chapter presents a NK DSGE model for the Belarusian economy. The set-up allows evaluating welfare losses generated by different monetary policy rules. The model employs some results of the two previous chapters for calibration of the parameters (in particular, shocks correlations and monetary policy response coefficients) and, within the scope of the thesis, it summarizes the analysis of the possible costs of the monetary union for Belarus relative to the free-floating exchange rate regime. For simplification reasons, the employed model features several limiting assumptions, therefore, the results presented below should be considered as preliminary. In a way, the main purpose of this chapter is setting the basis for further research.

5.1 Introduction to the DSGE Modeling for a Small Open Economy

New-Keynesian dynamic stochastic general equilibrium (NK DSGE) structures allow modeling economic systems and their business cycles under the assumption of incomplete markets, i.e. under imperfect competition and nominal rigidities that render monetary policy non-neutral. Consequently, NK DSGE setting has become a useful tool to evaluate different monetary policy rules. One of the advantages of the NK DSGE over VAR models is the overcoming of the Lucas critique. The critique targets monetary policy analysis by the means of aggregate macroeconomic variables, as it is hard to impossible to differentiate between the pure shock and the impact of the monetary policy. The

NK DSGE models are built on structural fundamentals and, in this way, can be more sophisticated. The model introduced below is based on the NK DSGE setting outlined by Gali & Monacelli (2002). The proposed model is designed for a small open economy with Calvo sticky prices; the economy is subject to domestic and foreign shocks.

Equilibrium dynamics of the economy is characterized by a system of equations for domestic inflation (new Keynesian Phillips curve), output gap (dynamic IS-type equation), and monetary policy rule:

New-Keynesian Philips curve: the NK DSGE characterizes inflation as a function of inflation expectations and output gap; the output gap in its turn can be expressed in terms of average marginal costs in the economy.

Output gap: the forward-looking IS curve connects output gap to nominal and natural interest rates.

Monetary rule: the rule describes how nominal interest rate is set by the monetary authority.

The NK DSGE model for the Belarusian economy was elaborated by the analysts of the NBB in the mid-2000s (Demidenko 2008) to provide medium-term forecasts. The NBB model's set-up allows for two effective monetary policy instruments - the short-term interest rate and the nominal exchange rate. Among exogenous variables affecting dynamics of the Belarusian economy, the model comprises the Russian output gap, the RUR/USD nominal exchange rate, the Russian CPI inflation, as well as the U.S. short-term interest rate and the U.S. CPI change. Although Demidenko (2008) emphasizes the importance of the developed model for communicating the objectives and actions of the NBB, no further results of the application nor development have been published since 2008. The most recent attempt to apply the NK DSGE framework to the Belarusian data was made by Zarecky (2012) , who also based his work on the model proposed by Gali & Monacelli (2002). Zarecky limits the analysis to the evaluation of the NBB reaction functions and compares welfare losses under three different sets of response coefficients to inflation and output gap. The major contribution of the paper is, however, calibration of the parameters employed in the model. Both Zarecky (2012) and Demidenko (2008) point out difficulties in applying the DSGE framework to the Belarusian data. The minor problems are related to data restrictions that complicate calibration of parameters. The major issues are related to high inflation expectations in Belarus and a weak role of the interest rate as the policy transmission channel, what complicates estimation of the models and their application for forecasting.

The model presented in this chapter analyses the welfare impacts under three monetary policy rules: hypothetical inflation targeting regime (by the independent central bank), proxy of the current monetary policy of the NBB, and imported monetary policy of the CBR (in case of the monetary union with Russia). The rest of the chapter is organised as follows: Section 5.2 outlines the model; Section 5.3 describes calibration of the parameters; Section 5.4 presents the results.

5.2 Model Set-up

5.2.1 Assumptions and Some Identities

Before proceeding with the households' and firms' optimization problems, we outline the assumptions and explain the most important identities. We set-up a model for Belarus as a small open economy. Instead of some proxy for the 'world', Russia is considered as the only neighbor, given its high share in the Belarusian trade and significant impact on the Belarusian economy as confirmed by the results from the previous chapters. It is assumed that bilateral trade turnover is negligible relative to the total consumption and production of Russia. Although some information is lost due to such choice, the setting corresponds to the objective of evaluating welfare costs of the possible monetary union. We model an economy with staggered prices a la Calvo, but for the time allow for flexible wages. Following Gali and Monacelli, we assume that the law of one price holds (i.e. there is no price discrimination for local and foreign consumers) and that the financial markets are complete. In addition, we keep the perfect foresight assumption, therefore, in the steady state, terms of trade are equal to 1, implying that in the equilibrium: PPP holds, domestic inflation is equal to CPI inflation, exchange rate is determined exclusively by the dynamics of the price level. Challenging the aforementioned assumptions in alternative specification could be used for the model enhancement during later research.

The main identities are specified below.

Composite consumption index: is a weighted sum of domestic- and foreign-produced goods that is determined by the openness of the economy (α) and the substitutability between domestic and foreign goods (η).

$$C_t = [(1-\alpha)^{1/\eta}(C_{H,t})^{(\eta-1)/\eta} + \alpha^{1/\eta}(C_{F,t})^{(\eta-1)/\eta}]^{\eta/(\eta-1)} \tag{5.1}$$

Demand functions and composite price indexes: are obtained by minimizing costs of consumption bundles and solving for optimal quantity of goods in terms of their prices, total price level in the economy and total consumption.

$$C_{H,t} = (1-\alpha)(\frac{P_{H,t}}{P_t})^{-\eta} C_t \tag{5.2}$$

$$C_{F,t} = \alpha(\frac{P_{F,t}}{P_t})^{-\eta} C_t \tag{5.3}$$

where $C_{H,t}$ - demand for domestic-produced goods, $C_{F,t}$ - demand for foreign goods, $P_{H,t}, P_{F,t}$ - domestic and foreign price indices, $P_t = [(1-\alpha)^{1/\eta}(P_{H,t})^{(\eta-1)/\eta} + \alpha^{1/\eta}(P_{F,t})^{(\eta-1)/\eta}]^{\eta/(\eta-1)}$ - consumer price index (CPI). In a special case when η is approaching 1, $P_t = P_{H,t}^{1-\alpha} * P_{F,t}^{\alpha}$.

Terms of trade and inflation: represent price of foreign goods in terms of domestic prices (ratio of import prices to export prices). Both $P_{F,t}$ and $P_{H,t}$ are given in one currency. $S_t = \frac{P_{F,t}}{P_{H,t}}$ or in logs:

$$s_t = p_{f,t} - p_{h,t} \tag{5.4}$$

By linearizing CPI equation around steady state ($P_{H,t} = P_{F,t} = \bar{P}$) and substituting with terms of trade:

$$p_t = (1-\alpha)p_{h,t} + \alpha p_{f,t} = (1-\alpha)p_{h,t} + \alpha(p_{h,t} + s_t) = p_{h,t} + \alpha s_t \tag{5.5}$$

Then, inflation in an open economy can be characterized as

$$\pi_t = p_t - p_{t-1} = \pi_{h,t} + \alpha \bigtriangleup s_t \tag{5.6}$$

Thus, inflation depends on readjustment of domestic prices, change in terms of trade and openness of an economy.

Nominal exchange rate : assuming that the law of one price holds and that there is only one global partner, we obtain
$P_{F,t} = \varepsilon_t P_t^*$, where P_t^* is the composite world (partner's) price index and ε_t - bilateral exchange rate (local currency per unit of foreign currency)

or in logs:

$$p_{f,t} = e_t + p_t^* \tag{5.7}$$

Real effective exchange rate (RER) : RER is defined as nominal exchange rate multiplied by the ratio of world price index to domestic CPI. In logs:

$$q_t = e_t + p_t^* - p_t \tag{5.8}$$

combining equations (5.4, 5.5, 5.7, 5.8) yields

$$q_t = s_t + p_{h,t} - p_t = (1-\alpha)s_t. \tag{5.9}$$

Interest-rate sharing : assuming complete capital markets, discount rate ($Q_{t,t+1}$) in all the economies is the same. Thus, domestic consumption can be derived as a function of world consumption index (C_t^*) and real effective exchange rate. In logs:

$$c_t = c_t^* + 1/\sigma q_t = c_t^* + 1/\sigma(1-\alpha)s_t \tag{5.10}$$

Uncovered interest parity : also arises from the assumption of complete markets - foreign and domestic bonds should have the same discount rate (when compared in one currency). In logs:

$$i_t - i_t^* = E_t[\Delta e_{t+1}] \tag{5.11}$$

where i_t and i_t^* stand for nominal interest rates.

5.2.2 Household's problem

Each representative household in a small open economy maximizes trivial life-long utility function:

$$maxU = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t)$$

s.t.

$$P_t C_t + E_t[Q_{t,t+1} D_{t+1}] \leq D_t + W_t N_t + T_t$$

where C_t represents composite consumption index (consists of domestic and imported goods); N_t - hours worked; P_t - consumer price index (includes prices of domestic as well as imported goods denominated in domestic currency); D_t stands for bonds (any other pay-off received from investment made in previous period); $Q_{t,t+1}$ - discount rate; $E_t[Q_{t,t+1}D_{t+1}]$ may be interpreted as present value of expected pay-off in next period; W_t - nominal wage; T_t - lump-sum taxes/transfers.
Utility function has the following form:

$$U(C_t, N_t) = \frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\varphi}}{1+\varphi}$$

By setting up Langrangian and maximizing the function with respect to C_t, N_t - control variables and D_{t+1} - state variable, we obtain the following F.O.Cs:

$$C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{5.12}$$

$$\beta(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+1}}) = Q_{t,t+1} \tag{5.13}$$

We can exactly log-linearize the above equations:

$$w_t - p_t = \sigma c_t + \varphi n_t$$

$$c_t = E_t(c_{t+1}) - 1/\sigma(i_t - E_t(\pi_{t+1}) - \rho)$$

where small-case variables denote logs of corresponding variables; $\rho = -log\beta$, π_t - CPI inflation, $i_t = log(R_t)$, with R_t standing for nominal interest rate and being equal to $\frac{1}{Q_{t,t+1}}$.

5.2.3 Firms' problem

Production function and marginal costs

We assume linear production function for each differentiated good j:
$Y_t(j) = A_t N_t(j)$, where $a_t = log(A_t)$ (technology shock) - follows autoregressive process $a_t = \rho_a a_{t-1} + u_t$ Total real production costs for a good j are equal to

$$TC = \frac{W_t N_t(j) - \tau W_t N_t(j)}{P_(H,t)} = \frac{W_t N_t(j)(1-\tau)}{P_(H,t)} = \frac{W_t Y_t(j)/A_t(1-\tau)}{P_(H,t)}$$

By taking derivative with respect to $Y_t(j)$ one obtains real marginal costs:

$$MC_t(j) = \frac{W_t/A_t(1-\tau)}{P_(H,t)}$$

or in logs:

$$mc_t = -\nu + w_t - p_{h,t} - a_t \tag{5.14}$$

where $\nu = -log(1-\tau)$, τ -employment subsidy.
Index for aggregate domestic output can be constructed analogically to consumption index:

$$Y_t = (\int_0^1 Y_t(j)^{(\epsilon-1)/\epsilon} dj)^{\epsilon/(\epsilon-1)} = Y_t(\int_0^1 ((\frac{P_t(j)}{P_t})^{-\epsilon} dj))$$

Consequently, hours worked can be represented as

$$N_t = \frac{Y_t}{A_t} Z_t,$$

where

$$Z_t = \int_0^1 ((\frac{P_t(j)}{P_t})^{-\epsilon} dj)$$

and in a first-order linear approximation approaches zero. Thus, log-linearized production function has a form of:

$$y_t = a_t + n_t \tag{5.15}$$

Calvo price-setting

It is assumed that each period the fraction $(1-\theta)$ firms readjust their prices. The price $\bar{P_{H,t}}$ is chosen such that the present value of future pay-offs is maximized. It is supposed, that once readjusted, the price will remain the same for k periods with probability θ^k.

$$max(\bar{P_{H,t}}) = \sum_0^{\infty} \theta^k E_t[Q_{t,t+k} Y_{t+k}(j)(\bar{P_{H,t}} - MC^n_{t+k})] \tag{5.16}$$

$\bar{P_{H,t}}$ should follow F.O.C

$$\sum_{0}^{\infty} \theta^k E_t[Q_{t,t+k} Y_{t+k}(\bar{P_{H,t}} - \frac{\epsilon}{\epsilon - 1} MC^n_{t+k})] \tag{5.17}$$

By substituting for $Q_{t,t+k}$ from Euler equation, dividing by $P_{H,t-1}$, log-linearizing around zero-inflation, and rearranging:

$$\bar{p_{h,t}} - p_{h,t-1} = \sum_{0}^{\infty} (\beta\theta)^k E_t[\pi_{h,t+k}] + (1 - \beta\theta) \sum_{0}^{\infty} (\beta\theta)^k E_t[\hat{mc}_{t+k}] \tag{5.18}$$

where $\hat{mc}_{t+k}$ is log-deviation of real marginal costs from steady state value: $\mu = log(\epsilon/(\epsilon - 1))$; where μ is a constant mark-up in a friction-less setting (no market power of individual firms is assumed).
Domestic inflation (in logs) is equal to

$$\pi_{h,t} = (1 - \theta)(\bar{p_{h,t}} - p_{h,t-1}) = \beta E_t[\pi_{h,t+1}] + \lambda \hat{mc}_{t+k} \tag{5.19}$$

where $\lambda = \dfrac{(1-\theta)(1-\beta\theta)}{\theta}$
Thus, domestic inflation is a function of real marginal costs and expected change in domestic price level.

5.2.4 Equilibrium

From market clearing condition output of good j is equal to its consumption at home and export abroad:

$$Y_t(j) = C_{H,t}(j) + C^*_t(j) = \tag{5.20}$$

$$= (\frac{P_{H,t}(j)}{P_{H,t}})^{-\epsilon}[(1-\alpha)C_t(\frac{P_{H,t}}{P_t})^{-\eta} + \alpha^* Y^*_t(\frac{P_{H,t}}{E_t P^*_t})^{-\eta}] =$$

$$= (\frac{P_{H,t}(j)}{P_{H,t}})^{-\epsilon} * Y^*_t[(1-\alpha)RER_t^{1/\sigma}(\frac{P_{H,t}}{P_t})^{-\eta} + \alpha^*(\frac{P_{H,t}}{E_t P^*_t})^{-\eta}]$$

where RER_t - real exchange rate (in levels) between home country and its global partner. Here, we assume $C^*_t = Y^*_t$. Second equality in (5.20) is derived from the assumption of complete capital markets (5.10). Consequently, aggregate domestic output can be represented as

$$Y_t = Y^*_t S^\eta_t [(1-\alpha)RER_t^{1/\sigma - \eta} + \alpha] \tag{5.21}$$

Equation (5.21) can be log-linearized around the steady-state (PPP condition holds, RER = 1):

$$y_t = y_t^* + 1/\sigma_\alpha s_t \tag{5.22}$$

where $\sigma_\alpha = \dfrac{\sigma}{(1-\alpha) + \alpha * (\sigma\eta + (1-\alpha)(\sigma\eta - 1))}$.

Combining equation (5.22) with the Euler equation one gets intertemporal condition for output of home country:

$$\begin{aligned} y_t = E_t[y_{t+1}] - 1/\sigma(i_t - E_t(\pi_{t+1}) - \rho) - \frac{\alpha\omega}{\sigma} E_t[\Delta s_{t+1}] = \\ = E_t(y_{t+1}) - 1/\sigma_\alpha(i_t - E_t(\pi_{h,t+1}) - \rho) + \alpha\Theta E_t(y_{t+1}^*) \end{aligned} \tag{5.23}$$

where $\omega = \sigma\eta + (1-\alpha)(\sigma\eta - 1)$ and $\Theta = \omega - 1$.

Second, marginal costs are expressed as a function of the home country's output, global output and terms of trade.
Recalling equations (5.14) for marginal costs, and in addition (5.5), (5.12) and (5.23):

$$mc_t = -\nu + \sigma y_t^* + \varphi y_t + s_t - (1-\varphi)a_t = -\nu + (\sigma_\alpha + \varphi)y_t + (\sigma - \sigma_\alpha)y_t^* - (1-\varphi)a_t \tag{5.24}$$

Hence, home inflation that depends on the real marginal costs can be eventually expressed in terms of a country's output, domestic productivity shock, and global output (that in turn is subject to the global productivity shock).

5.2.5 Key equations

The key equations of the model are summarized below.

NKPC: output gap is defined as $x_t = y_t - \bar{y}_t$, where $\bar{y}_t$ - equilibrium output level, derived from (5.25) when $mc_t = -\mu$:

$$\bar{y}_t = \Omega + \Gamma a_t + \alpha\psi y_t^* \tag{5.25}$$

where $\Omega = \dfrac{\nu - \mu}{\sigma_\alpha + \varphi}, \Gamma = \dfrac{1+\varphi}{\sigma_\alpha + \varphi}, \psi = -\dfrac{\Theta\sigma_\alpha}{\sigma_\alpha + \varphi}$. Combining with (5.19) yields:

$$\pi_{h,t} = \beta E_t[\pi_{h,t+1}] + k_\alpha x_t \tag{5.26}$$

where $k_\alpha = \lambda(\sigma_\alpha + \varphi)$.

IS curve: forward-looking curve is derived from (5.23)

$$x_t = E_t[x_{t+1}] - 1/\sigma_\alpha(i_t - E_t(\pi_{h,t+1}) - r\bar{r}_t) \tag{5.27}$$

where $r\bar{r}_t = \rho - \sigma_\alpha\Gamma(1-\rho_a)a_t + \alpha\sigma_\alpha(\Theta + \psi)E_t\Delta y^*_{t+1}$ - natural interest rate of a small open economy.

In contrast to the closed economy, the small open economy is influenced by the degree of its openness (α): it affects the sensitivity of the output gap to the interest changes and links the natural interest rate to expected foreign output growth.

5.2.6 Optimal Monetary Policy and Welfare Loss Function

Recalling the closed economy New-Keynesian framework, Gali & Monacelli (2002) state that the optimal monetary policy for a small open economy is also the one that replicates the flexible price equilibrium allocation. In a small open economy there are two main sources of distortion that combined with price-stickiness render monetary policy non-neutral: 1) market power of firms and 2) incentive to influence terms of trade in a beneficial way to a home economy. The latter results from the imperfect substitutability between domestic and foreign goods. These distortions can be eliminated by introducing employment subsidy (τ) that enters real marginal costs and keeps them at their steady state level ($-\mu$). It can be shown that for a special case, when $\sigma = \eta = \gamma = 1$, τ should be set such that $(1-\tau)(1-\alpha) = 1 - \frac{1}{\epsilon}$. By stabilizing mark-ups in this way, nominal rigidities are no longer binding, since firms do not have any incentive to adjust prices, while the monetary authority does not have any desire to improve the terms of trade. Flexible price equilibrium allocation implies stabilization of output gap ($x_t = 0$ for all t) and domestic price level ($\pi_{h,t} = 0$ for all t). Consequently, nominal interest rate (i_t) under optimal policy is equal to the natural interest rate, i.e. it changes only in response to the real domestic and foreign productivity shocks. Gali and Monacelli show that under particular assumptions $\sigma = \eta = \gamma = 1$, the policy of strict domestic inflation targeting corresponds to the optimal policy (the one stabilizing the output gap). Alternative policy rules can be evaluated in terms of the implied welfare losses.

Welfare loss function is derived as a second order approximation to the utility losses of a representative household. Gali and Monacelli represent it in terms of the variance of domestic inflation and the output gap:

$$L = -\frac{1-\alpha}{2} * (\epsilon/\lambda * var(\pi_{h,t}) + (1+\varphi) * var(x_t)) \tag{5.28}$$

5.2.7 Monetary Policy Rules

The model analyses the following rules:

CPI inflation targeting models the Belarusian economy with hypothetical independent central bank that directly reacts only to price changes; we consider the CPI inflation as the target, since, currently, the NBB formulates its goal by referring to that indicator. Moreover, the available statistical data does not differentiate between the domestic and the imported inflation, thus, complicating calibration of the parameters:

$$i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi \pi_t). \tag{5.29}$$

CPI inflation and output targeting approximates current monetary policy of the NBB, which may be subject to the inflationary bias:

$$i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi \pi_t + \phi_x x_t). \tag{5.30}$$

Exchange rate targeting forecasts dynamics of the Belarusian economy in case of possible monetary union with Russia:

$$e_t = 0. \tag{5.31}$$

As can be seen, we also allow for persistence of the policy rules, assuming some willingness of the monetary authorities to limit fluctuations of the nominal interest rates. As it cannot be assumed that Russia has achieved zero inflation, we add equations describing inflation in Russia, evolution of the Russian real marginal costs, and the policy rule of the CBR reacting to both inflation and the productivity shock. Appendix B contains the full set of equations used in the model.

5.3 Calibration of parameters

The focus of the present work is to compare welfare losses for the Belarusian economy that may result, in particular, due to misalignment of the business cycles with the potential anchor - Russia. Therefore, we concentrate on the calibration of the parameters related to the shocks characteristics and to the policy functions of the monetary authorities. As to the other parameters, for the time being, we make simplified assumptions that could be challenged and reviewed during later works on this topic.

Following Gali & Monacelli (2002), we set $\sigma = 1$ for both countries. Thus, we assume that the households are risk-neutral and the utility function has logarithmic form (Zarecky calibrated σ using the Belarusian data on consumption and real wages and obtained the parameter equal to 1.16). Parameter ϕ can be proxied as wage elasticity of labor supply. Given low variability of the officially registered unemployment in Belarus (see Chapter 2, we set ϕ equal to 3, which implies low elasticity of labor. We also suppose perfect substitutability of the domestic and foreign goods by fixing $\eta = 1$. As to the elasticity of substitution between goods produced within one country (ϵ), following other researchers, we fix it equal to 6 (consequently, mark-up constitutes 18.23%) for both economies. Discount factor β is estimated as $(1/(1+r))$, where r - the natural interest rate, which is proxied by the average real interest rate on new deposits in the national currency in 2000:Q1 - 2010:Q2 (excluding the period of the currency crisis for Belarus). We obtain $\beta = 0.98$ ($r = 5.5\%$ annualized $\approx 1.03\%$ to be used in the model, where one period is equivalent to one quarter) for Belarus and $\beta = 0.99$ ($r = 3.5\%$ annualized) for Russia. Price stickiness θ is set as in Zarecky (2012) at 0.55 for Belarus. The author motivates the choice by fast pass-through of the exchange rate fluctuations and high inflation expectations to prices. At the same time, goods and serves, subject to regulated pricing, constitute about 20% of the CPI basket (Zarecky 2012); thus, for a sensitivity check, we will also use a higher θ. For Russia, the price rigidity indicator is made equal to 0.75 (similar to studies of other countries). Openness α is estimated as imports from Russia over GDP (average for the last three years: 2009 - 2012) - 0.55.

Shock persistence coefficients are calibrated by fitting AR(1) process to the seasonally adjusted HP-filtered time-series of quarterly log GDP of Belarus and Russia (quite strong assumption that the output shock is only due to the productivity shock). By estimating data from 2000-2012 we obtain the

following coefficients of shock persistence:
Belarus: 0.760; Russia: 0.862; shock correlation: 0.806 / 0.506

We use two alternative values for shock correlation: the first corresponds to shock synchronization in the period 2005-2009:Q4, which was characterized by the highest alignment of the economies (Section 3.1), shocks are proxied with the GDP-gap; the second corresponds to the correlation of supply shocks recovered using the Blanchard and Quah procedure (Section 3.2). From theoretical point of view, such shocks, when distinguished from temporary disturbances, may better proxy unobserved productivity fluctuations.

Response coefficients for the policy rules targeting both inflation and output gap are calibrated based on the analysis performed in Subsection 4.2.2. In this way, we set substantial persistence coefficients for the policy rates and assign a stronger reaction to inflation for the CBR relative to the NBB.

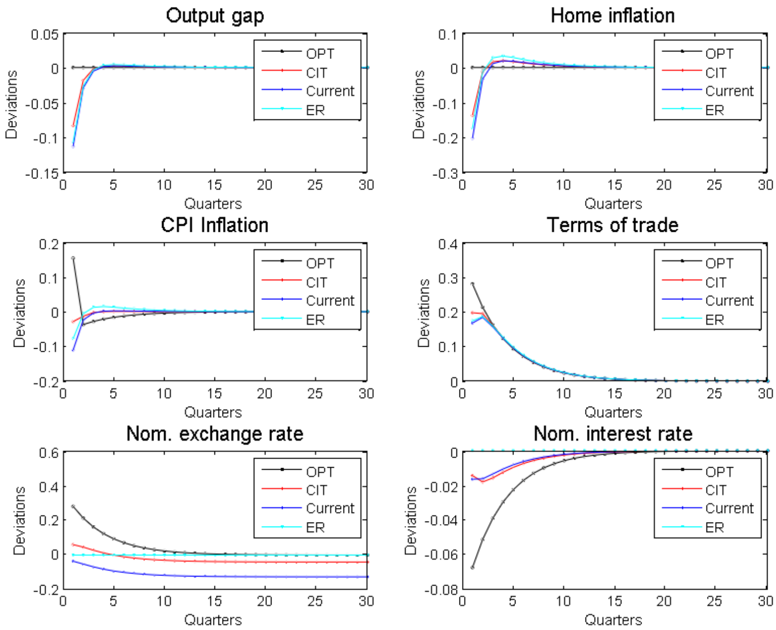
5.4 Discussion of results

In order to evaluate relative performance of different monetary policy regimes, we simulate domestic and global productivity shocks and investigate the behavior of major variables under alternative policy rules. Following our discussion on the optimal monetary policy in a small open economy, we set $\pi_{h,t} = 0$ as a benchmark regime that replicates flexible price equilibrium allocation and results in zero welfare loss. Three other rules are evaluated relative to the benchmark regime; the criteria are variance of output and domestic inflation. Impulse responses to a domestic shock are presented in Figure 5.1. Here, shock correlation is set to 0.5 and price stickiness coefficient for Belarus to 0.55. Behavior of the variables under stronger shock correlation is similar, but, as expected, is less volatile (see the electronic supplement, *ch5/output*).

Welfare losses in terms of the output and domestic inflation volatility for four regimes are presented in the Table 5.1 to complement the analysis. We consider losses generated under different correlation coefficients of domestic and foreign productivity shocks. Besides, we investigate how the estimates change depending on the price stickiness coefficient.

A positive domestic productivity ($\approx$ aggregate supply) shock increases natural output level. In case the nominal interest rate is equal to the natural interest rate (which reacts negatively to the shock in order to support transitory increase of output and consumption), actual output becomes equal to its natural level, and neither output gap, nor domestic inflation from price read-

Figure 5.1: Impulse responses to a domestic productivity shock,%



Source: own computations.

OPT - $\pi_{h,t} = 0$, CIT - CPI inflation targeting, Current - proxy of the current NBB rule, ER - $e_t = 0$

Table 5.1: Welfare losses of alternative monetary policy regimes

Parameters' values	**OPT**	**CIT**	**Current**	**ER**
shocks correlation = 0.80				
$\theta = 0.50$	0	-0.0847	-0.2177	-0.1362
$\theta = 0.75$	0	-0.1525	-1.1985	-0.2270
shocks correlation = 0.50				
$\theta = 0.50$	0	-0.0796	-0.1863	-0.1413
$\theta = 0.75$	0	-0.1439	-1.0125	-0.2409

Source: own calculations.

justment occurs. Otherwise, if the monetary policy fails to accommodate the shock, it will result in the deviations of the variables from their natural levels and consequent welfare losses.

For the optimal rule, output and inflation gap, by construction, are set to zero. Their stabilization is achieved by high variability of nominal interest rate, which, given stable interest rate in Russia (in the absence of a shock), leads to depreciation of the exchange rate and increase in the terms of trade. Owing to high calibrated openness parameter, CPI index increases significantly with the growth of the foreign price index.

Under the CPI targeting regime, we assume that a hypothetically independent central bank sets the nominal interest rate to stabilize the CPI inflation. Such regime may proxy inflation targeting with managed floating of the exchange rate. A positive domestic productivity shock requires real depreciation, leading to increase in the CPI. In order to limit such fluctuation, monetary authorities need to achieve smaller increase of the terms of trade. Thus, initially, we observe more contractionary monetary policy (higher nominal interest rate) compared to what is needed to ensure immediate shock transition. This results in negative output gap and decrease in domestic prices (to the extent of price stickiness). Then, the more rigid domestic prices are, the longer shock accommodation will last. For example, when the price stickiness coefficient is set to 0.75, it takes 3 quarters more for output to reach its natural level, and the welfare losses associated with the CPI targeting increase.

Exchange rate targeting regime assumes import of the Russian monetary policy. In the absence of productivity shock in Russia, nominal interest and exchange rates remain constant and cannot facilitate transition of an idiosyncratic shock in Belarus. Consequently, a shock can be accommodated in the economy only through decrease in domestic prices, which, to some extent, manage to increase the terms of trade and contribute to elimination of a negative output gap. Thus, price rigidity becomes an important issue. The losses generated under $\theta = 0.55$ (i.e. prices are readjusted every 2 quarters) are lower than those occurring with more staggered pricing ($\theta = 0.75$ presumes that prices are fixed for one year). Another important factor is shock correlation: the losses slightly decrease, when common incidence of productivity shocks in Belarus and Russia is set at a higher level. Based on our results, though, increase in price flexibility seems to be more important for reducing losses from fixing the exchange rate. In terms of welfare costs, exchange rate targeting regime is inferior to the CPI targeting. Notwithstanding, difference in performance of the two regimes becomes smaller when shock correlation and price flexibility increase. In addition, if openness of Belarus increased, the weight of the Russian prices in the CPI would grow and the inflation-targeting regime would approach the fixed exchange rate arrangement. Meanwhile, both CPI and the exchange rate targeting outperform a proxy of the current NBB monetary policy, for which we assumed less strict response to inflation fluctuations (as compared to the CIT and the CBR responses) and possibility of inconsistent reaction to the output gap.

The latter observation opens an interesting discussion. Both regimes (inflation targeting and monetary union) will become feasible, once the Belarusian economy undergoes important transformations. Hence, the question on the optimal monetary policy stated in the beginning of the thesis could be substituted by the one asking, which regime is faster and more realistically to achieve. Based on the above NK DSGE results, price flexibility is a significant factor of successful CPI inflation targeting, and due to presence of regulated prices, it is hard to affirm that Belarus has achieved high flexibility. Limitations of the model did not allow us to make further conclusions. But, according to the findings in the previous chapters, unanchored inflation expectations and low operationability of conventional monetary transmission channels seem to be major obstacles for independent monetary policy of the NBB. Thus, the necessary steps towards efficient inflation targeting are establishing credibility and independence of the NBB together with removing rigidities in the economy, many of which are related to strong presence of the state sector, overregulated and still underliberalized markets. As to the possible monetary union, the NK DSGE demonstrated importance of price flexibility and shock correlation. If Belarus aimed on the monetary integration with Russia, some additional structural alignment would be desired in order to increase shock synchronization. This could be done, for instance, by intensifying ownership links and intra-industry trade. Relaxing other rigidities that were not explored within the scope of this work (notably, staggered wages and financial frictions) and aligning monetary transmission mechanisms could be equally relevant. Therefore, some important transformations (mostly related to increasing flexibility of the Belarusian economy) are needed for successful implementation of both regimes. Based on current trends, it might seem more feasible for Belarus to become deeper integrated with Russia than to anchor inflation expectations and establish trust to the BYR. Not to overestimate perspectives of the monetary union, however, one has to keep in mind other costs that were absent from our analysis: possible political pressure, social tensions, as well as vulnerable credibility of the CBR itself.

The above results, in a way, summarize possible costs of monetary union for the Belarusian economy. Still, the employed model features many simplifying assumptions and can provide only rough estimation of welfare costs. Elaboration and estimation of a more sophisticated model that would better account for the countries' specific features requires a separate study and is beyond the scope of the present thesis. Possible extensions of the work may include: adding inflation expectations in Belarus (departing from the assumption of fully rational expectations and modeling deterministic shocks); accounting for other rigidities (wage stickiness and financial frictions); introducing a third sector (the rest of the world) and accounting for foreign shocks in Russia; having explicit fiscal authority due to the large presence of the state sector in Belarus.

Chapter 6

Conclusion

In the thesis, we applied the OCA framework to evaluate feasibility of the possible monetary union between Belarus and Russia. Within the scope of the present work, we concentrated on the alignment analysis of the two economies in order to infer on some potential costs of such arrangement for Belarus.

Our first proposition was that despite long-dated history of integration, there is significant cyclical and structural misalignment between the countries due to asymmetry of shocks and different specializations of the economies. Dynamic correlation analysis of the economic activity indicators revealed that the countries' cyclical alignment peaked in 2005-2009 (average correlation of the output growth rates amounted to 80%), but the symmetry has decreased since the end of 2009, mostly due to different recovery paths undertaken after the 2008-2009 crisis. By the means of a structural VAR with long-run restrictions we showed that temporary (demand) shocks were not symmetric, except for the recession in 2008-2009, while the correlation of the permanent (supply) shocks constituted about 50% in 2000-2009 and has also declined since 2010. Structural similarity of the economies was evaluated qualitatively using Landesmann and Grubel-Lloyd indices. Sound manufacturing and agricultural sectors distinguish the Belarusian economy from the Russian. Relatively low intra-industry trade share (30%) and prevalence of vertical trade likewise point on differences in the economies' structures and specializations. Ownership links with Russia (characterized by the FDI stocks and inflows) are strong compared to the rest of the world, but their weight relative to the Belarusian GDP is low, and, for the time, they hardly contribute significantly to the cyclical alignment of the economies. We conclude that the countries are, in general, subject to common external and permanent fluctuations; the effects and transmission of shocks in the economies as well as responses to them, meanwhile, are not uniform. The potential costs of the monetary union for Belarus may be high mostly due to the structural misalignment. Intensification of the ownership links and increase in the intra-industry trade prior to the monetary integration could reduce the losses from the fixed exchange rate arrangement.

The second hypothesis questioned the congruency between the monetary policy responses to shocks in Belarus and Russia and their transmission mechanisms. We calculated and compared the implied policy rates and estimated policy response functions (Taylor rules) additionally allowing for asymmetric reactions of the central banks during recessions and expansions. We complemented the analysis with the estimation of a monetary VAR model. The obtained results are not uniform in relation to the costs of the monetary union. From the factors that speak for the monetary integration, we shall mention high cyclical alignment in 2005-2010, as demonstrated by the implied Taylor rules; more aggressive monetary policy of the CBR; mainly nominal impact of the NBB monetary policy; importance of the Russian shocks for the Belarusian economy. From another side, the conducted analysis revealed a number of factors that could generate high costs of fixing the exchange rate. The monetary policy transmission channels in Belarus and Russia are operational to different extents. Distinct interest rate pass-throughs to output indicate that the Belarusian economy is less sensitive to the cost of credit, what can be a consequence of high weight of the state sector in the Belarusian economy and its reliance on directed crediting. Reported differences in the countries' exchange rates fundamentals supported our previous conclusion on the structural misalignment between the economies.

In order to quantitatively summarize our findings, we estimated welfare losses for the Belarusian economy that could be associated with the possible monetary union relative to the alternative policy regimes (the inflation targeting and the current monetary policy rule). For this purpose, we set up a simple NK DSGE model for Belarus as a small open economy, where we employed some results of the preceding analysis for calibration of parameters (in particular, shocks correlations and monetary policy response coefficients). According to the obtained results, the fixed exchange rate arrangement outperformes the proxy of the currently applied monetary policy of the NBB, while being inferiour to the CPI inflation targeting (conducted by hypothetically independent central bank). We also showed that difference between the two latter regimes becomes smaller when price flexibility and shocks correlation increase.

The main contribution of the present thesis was in its attempt to evaluate the alignment of the Belarusian and Russian economies and, consequently, to identify some costs of the possible monetary union. Extensions of this work may involve accounting for the time variability and asymmetries of the key equations used to describe the economies, as well as setting up more sophisticated NK DSGE model that would better capture specific features of the Belarusian and Russian economies and provide more precise estimations of the costs associated with the monetary union. It should be also noted that within the scope of this thesis, we concentrated only on possible economic costs that may arise as a result of abandoning own monetary policy. Analysis of other costs, including those of social and political nature, could equally become subject of further research.

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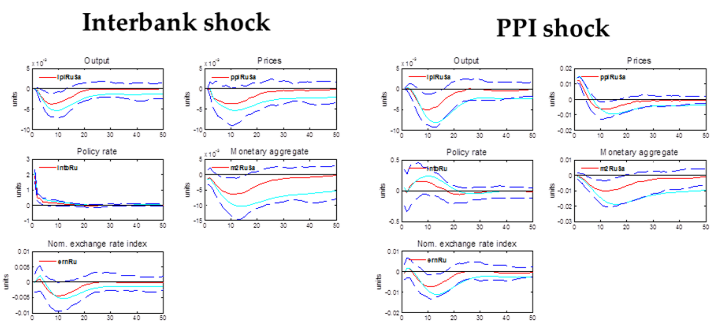
Appendix A

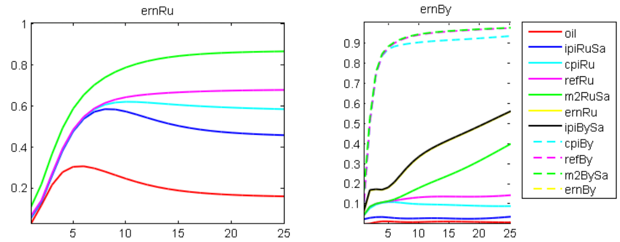
Additional output from empirical estimations

Figure A.1: Impulse responses to an interbank rate and PPI shock in Russia (1 st.dev shock), units



Source: own computations.

Figure A.2: Variance decomposition of the BYR and RUR nominal exchange rates (baseline model)



Source: own computations.

Table A.1: Model Checking. Baseline Monetary VAR

Cointegration Test

Johansen test

Number of equations = 11
Lag order = 2
Estimation period: 2000:05 - 2012:12 (T = 152)
Case 5: Unrestricted trend and constant

Log-likelihood = 4516.33 (including constant term: 4084.97)

Rank	Eigenvalue	Trace test	p-value	Lmax test	p-value
0	0.65242	547.62	[0.0000]	160.63	[0.0000]
1	0.50916	386.99	[0.0000]	108.17	[0.0000]
2	0.39409	278.83	[0.0000]	76.156	[0.0005]
3	0.32458	202.67	[0.0006]	59.649	[0.0151]
4	0.21847	143.02	[0.0282]	37.468	[0.5090]
5	0.19364	105.55	[0.0633]	32.714	[0.4538]
6	0.12560	72.837	[0.1390]	20.401	[0.8743]

Causality Tests

Conducted for seasonally differenced series

	Granger causality *(pval-F)*	**Instantaneous causality *(pval-Chi)***
joint	0.000	0.0567
ipiBy_dseas	0.000	0.8573
cpiBy_dseas	0.3206	0.6558
refBy	0.1049	0.1408
m2By_dseas	0.1852	0.003
ernBy_dseas	0.1497	0.0153

Granger causality
H0: variable does not Granger-cause "oil_dseas, ipiRu_dseas, cpiRu_dseas, refRu, m2Ru_dseas, ernRu_dseas".

Instantaneous causality
H0: Covariance between the error vectors is equal to zero.

Stability Test

modulus of the eigenvalues of the inverse characteristic polynomial:
|z| = (27.9439 4.5885 4.5885 7.0706 7.0706 1.7971 1.7971 1.1167 1.1167 2.0158 2.0158 1.8077 1.3095 1.3095 1.2681 1.2681 1.1123 1.1123 1.1105 1.0078 1.0255 1.0694)

Source: own computations.

Appendix B

Equations of the DSGE Model

To set up the model we used equations log-linearized around their steady states.

Endogenous variables: $\pi_{h,t}$ - domestic inflation, x_t - output gap, r_t - domestic nominal interest rate, $rnat_t$ - natural interest rate, a_t - domestic productivity, y_t - domestic output, $\bar{y}_t$ - domestic natural output, s_t - effective terms of trade between the country and the world, π_t - CPI inflation, q_t - real exchange rate, e_t - nominal exchange rate, $p_{h,t}$ and p_t domestic price level and CPI price level, c_t - consumption, nx_t - trade balance, $\pi_{glob,t}$ - global inflation (here and further, $glob$ corresponds to the Russian variables as it is the only foreign partner in the model), $y_{glob,t}$ - global output, $a_{glob,t}$ - global productivity, $r_{glob,t}$ - global interest rate. Variables a_t, $a_{glob,t}$, r_t, $r_{glob,t}$, s_t, e_t are treated as state (i.e. predetermined) variables. "Natural" denotes behaviour of variables in the frictionless (flexible price) setting.

First, we introduce equations that describe different home monetary policy rules - one of the following rules can be chosen to run the code.

1. $\pi_{h,t} = 0$ - benchmark rule corresponding to the optimal policy; denotes strict inflation targeting that implies stable price level of domestic goods, no inflationary bias of the Central Bank and, thus, no output gap.
2. $r_t = \rho_r * r_{t-1} + \phi_\pi * \pi_t$ - CPI inflation targeting.
3. $r_t = \rho_r * r_{t-1} + \phi_\pi * \pi_t + \phi_x * x_t$ - Taylor rule; the central bank reacts to both inflation and output gaps.
4. $e_t = 0$ - exchange rate targeting.

Russia is modeled as the closed economy. Thus, the policy rule is represented as:

5.$rglob = \rho_{rglob} * rglob_{t-1} + (1 - \rho_{rglob}) * (\phi_{\pi_{glob}} * \pi_g lob_t + \phi_{gapglob} * aglob_t)$.
Thus, we also allow for some persistence of the policy rate. Here, $\phi_{gapglob} =$

$-\dfrac{\sigma * (1+\varphi) * (1-\rho_{aglob})}{\varphi+\sigma}$.

Home and global productivity are subject to random shocks:

6. $a_t = \rho_a * a_{t-1} + shock_a + correl_{a,aglob} * shock_{aglob}$;

7. $a_{glob,t} = \rho_{aglob} * aglob_{t-1} + shock_{aglob}$.

where $shock_a, shock_{aglob} \sim N(0, \sigma_a^2)$.

Further, we refer to the equations containing other variables of home and global economies.

8. $\pi_{h,t} = \beta * \pi_{h,t+1} + \kappa * x_t$ - Philips curve.

9. $x_t = x_{t+1} - 1/\sigma_\alpha * (r_t - \pi_{h,t+1} - rnat_t)$ - IS curve.

10. $rnat_t = \rho - \sigma_\alpha * \Gamma * (1-\rho_a) * a_t + \alpha * \sigma_\alpha * (\Theta + \psi) * (y_{glob,t+1} - y_{glob,t})$ - natural interest rate. Note that in the code ρ is set to 0, since we use equations that are log-linearized around the steady state (deviation of a constant from the steady state = 0). For the same reason, constant ρ is also dropped in the monetary policy rules.

11. $y_t = x_t + \bar{y_t}$ - characterizes output gap as a deviation of actual output from its natural (flexible-price) state. Deviation is a result of market frictions.

12. $\bar{y_t} = \Omega + \Gamma * a_t + \alpha * \psi * y_{glob,t}$ - natural output that depends on the productivity shock and global output that in its turn is a function of global productivity shock. !Note that in the code Ω is set to zero. It is assumed that the fiscal authority acts optimally, thus, employment subsidy is set such as to eliminate the market frictions ($\mu = \tau$); therefore $\Omega = 0$.

13. $\pi_t = \pi_{h,t} + \alpha * (s_t - s_{t-1})$ - represents CPI inflation and also characterizes intertemporal terms of trade.

14. $s_t - s_{t-1} = e_t - e_{t-1} + \pi_{glob,t} - \pi_{h,t}$ - represents dynamics of nominal exchange rate.

15. $y_t = y_{glob,t} + 1/\sigma_\alpha * s_t$ - international risk sharing condition.

16. $y_t = a_t + n_t$ - production function.

17. $c_t = y_{glob,t} + (1-\alpha)/\sigma * s_t$ - market clearing condition.

18. $nx_t = \alpha * (\omega/\sigma - 1) * s_t$ - trade balance.

19. $q_t = (1-\alpha) * s_t$ - real exchange rate.

20. $p_{h,t} = \pi_{h,t} + p_{h,t-1}$ - domestic price level.

21. $p_t = \pi_t + p_{t-1}$ - CPI price level.

22. $\pi_{glob,t} = \beta_{glob} * \pi_{glob,t+1} + \lambda_g lob * mc_{glob,t}$; - inflation in Russia.

23. $mc_{glob} = (\sigma + \phi) * y_{glob,t} - (1+\phi) * a_{glob,t}$; - real marginal costs in Russia.

24. $y_{glob} = y_{glob,t+1} - (r_{glob} - \pi_{glob,t+1})/\sigma$; - output equation for Russia.

Appendix C

Content of Electronic Supplement

There is an electronic supplement to this thesis, which contains additional output, empirical data, and MatLab and Gretl source codes.

- ch3: quarterly dataset; MatLab code for calculations performed in Chapter 3 (including estimation of a SVAR with long-run restrictons).
- ch4: monthly dataset; Gretl code for estimation of monetary rules; MatLab code for estimation of monetary VAR; MatLab outputs for four alternative VAR specifications.
- ch5: example of a dynare code; output figures with impulse responses to domestic and foreign productivity shocks under different sets of parameters (1. high price flexibility (0.55) and high shock correlation (0.80) and 2. low price flexibility (0.75) and low shock correlation (0.50)).